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WATER METERS.

COMPARATIVE TESTS OF ACCURACY, DELIVERY, ETC.—DISTINCTIVE FEATURES OF THE WORTHINGTON, KENNEDY, SIEMENS AND HESSE METERS.

By ROSS E. BROWNE, Mem. Tech. Soc.

From Transactions of the Technical Society of the Pacific Coast.

With the purpose of employing a meter for the measurement of water, in connection with some hydraulic experiments conducted at the University of California, the writer instituted a series of tests of a meter invented by Prof. F. G. Hesse. The accuracy, at various rates of delivery, was carefully determined. The results of these experiments, properly tabulated, furnish a correction for the indicated delivery. It is believed that, where the flow is uniform, the possible error in the corrected index reading may be safely placed at ½ per cent.

The meter is of the class known as *velocity* or *inferential* meters, and is so permanent in its sources of error, as to make it peculiarly adapted to the purpose named.

These experiments led to comparative tests of the Worthington meter. Reliable information was also sought concerning other meters in common use. It is thought that sufficient of interest was developed to warrant this paper, particularly as, in the course of this investigation, it was noted: that no great amount of accurate and systematic information upon this subject is to be found in the available files of our engineering and scientific journals; that the several reports consulted, of engineers and superintendents of water works, while well answering their immediate purposes, do not furnish facts in sufficient detail to guide the independent judgment of one not familiar with the construction of the meters in competition; that very few of the circulars of the American manufacturing companies supply such data as will answer for comprehensive comparison.*

It will be attempted to bring forward, as fairly as may be, the distinctive features of two of the principal forms of Piston meter—the Worthington and the Kennedy,—and three forms of velocity meter—the Siemens of English manufacture, the Siemens of German manufacture, and the Hesse meter already mentioned.

The Worthington is widely known in the United States. The Kennedy is one of the most perfect of the meters used in England. The two Siemens meters are probably the most extensively employed in Europe. The Hesse meter has been but recently perfected, and not yet introduced. If undue prominence has been given to the last named meter, the inter-

* The circular of the National Meter Co. of New York is exceptionally complete, though there is missing some of the data necessary to warrant the inclusion of their rotary Crown Meter in the list of meters discussed.

est of the writer in his special investigation must plead as excuse.

It is to be regretted that this list cannot be made more comprehensive by adding an example of the rotary piston form, such as the Crown. It will be understood that, in speaking of the piston meter, special reference is only intended to the Worthington and the Kennedy.

These meters will be considered in the main with reference to their adaptability to house use, or use in the sale by volume of water under pressure.

This being the purpose of a meter, it should fulfill the following conditions:

1st. It should register with a suitable degree of accuracy, the quantity of water delivered at every rate of flow, from that of the maximum capacity of the service pipe, to a rate so small as to discourage theft. The admissible error is variously placed at from 2 to 5 per cent.

2d. This degree of accuracy should be reasonably permanent, *i. e.*, the meter should not be subject to any change, seriously affecting its accuracy, by wear, by slight deposition of sediment, etc. Sudden opening and closing of the house faucets should not induce any considerable error of registry.

3d. The introduction of the meter should not materially affect the delivery of the service pipe; *i. e.*, should cause no serious loss of effective head or pressure.

4th. The price should be small and the necessary repairs inexpensive.

Notwithstanding the demand and the effort made by inventors to meet these desiderata, such marked success has not been attained as to make it a universal custom to sell water by the volume.

In the systems of city supply, there result decided advantages from the employment of the meter. Reckless waste is checked and the consumer is not charged for his neighbors' extravagance. A number of comprehensive articles have been published upon this subject, and a few points only will be reiterated.

It is claimed that nearly one-half of the water consumed in our cities is uselessly wasted. It is doubtful if this lavish consumption is on the whole a sanitary benefit, the waste being in large part the result either of leakage or of willful negligence, and not of a character to effect any proper flushing of closets and sewers. By placing meters near the point where the service pipes enter the premises, and thus making the consumers responsible for such negligence, and for defective plumbing, a wiser use of water is effected. In order to prevent the penurious consumer from pursuing an economy so stringent as to result in certain sanitary evils, it is recommended that a minimum quantity of say 10 or 20 gallons per capita per diem be established, and the consumer charged for this whether he use it or not. The water department of Providence, R. I., makes a minimum charge of $10 per year (equivalent to about 100 gallons per diem) for each meter service. Meters were provided, in Providence, for about one-half the total number of services, and a decided economy effected. The daily consumption at present is about 350 gallons per service, or 25 to 30 per capita—less than one-half the average in American cities.

When the water supply of a city, employing few meters, becomes inadequate to meet the demands of the consumers, two propositions may be entertained: the increasing of the capacity of its water works, and the introduction of meters. It is maintained that in most cases the latter proposition is by far the more economical. As the city grows, it will, from time to time, become necessary to increase the supply; but it is thought much cheaper to keep the meters in repair and maintain water works of double the capacity sufficient without meters.

It seems inevitable that the meter system should rapidly grow in favor with improvement of the present forms of meter. In a few cities their use is already extensive. In London* nearly 40 per cent. of the houses supplied by the various water companies are now provided with meters. In New York and Boston, meters have been introduced into from 5 to 10 per cent. of the services. In Providence, R. I., 50 per cent. In San Francisco 20 per cent. In Oakland 3 or 4 per cent.

THE COMPARISON OF METERS.—A just and comprehensive comparison of the merits of competing meters will frequently involve an extended investigation. If, for instance, the extent and effect of wear and rusting are difficult to estimate, prolonged trial may become necessary.

Of the more important considerations

* See *London Engineer* of Aug. 1, 1884. For detailed information concerning the U. S. and Canada, see circular of National Meter Co., N. Y.

in such a comparison, the following are enumerated in an order not pretending to indicate relative importance.

Delivery under various effective heads.

Greatest advisable rate of delivery.

Accuracy of registration at various rates of delivery.

Sensitiveness.

Necessity and difficulty of special adjustment.

Permanence of initial degree of accuracy and sensitiveness.

Liability to obstruction.

Compactness.

Price, both upon the basis of delivery and of greatest advisable effective head.

Expense of repairs, including the consideration of the life of the meter.

Head lost in the meter.—By head lost is understood the difference of the heads in the inlet and the outlet openings. If H is the actual head at the inlet and h that at the outlet, then the head lost is $H-h$. The rate of delivery will depend upon this difference of heads, and not upon the actual magnitude of H and h.

In each of the meters described, the law of loss of head is, within a practical limit, roughly the same—the resistance being mainly due to impact and fluid friction, and therefore approximately proportional to the square of the rate of delivery.

This is about the same as the law of loss in a pipe. Hence the loss of head in a meter is fittingly indicated by the length of pipe of given diameter which will cause the same loss. Thus 10 feet of $\frac{1}{2}$-inch pipe, or 30 feet of $\frac{3}{4}$-inch pipe, will occasion the same loss as the Worthington $\frac{5}{8}$-inch or the Hesse $\frac{1}{2}$-inch meter.

Effective head.—By effective head is understood the actual head necessary to force water through the meter at a given rate. This is equal then to the "head lost" plus the velocity head in the outlet pipe, and will, in the meters mentioned, be very little greater than the "head lost."

Delivery of the meter.—It is customary to designate the size of a meter by the diameter of service pipe for which the inlet and outlet openings are fitted. This classification furnishes no general measure of delivery. When the rate of delivery is approximately the same function of the head lost, in each, it is admissible to adopt a unit and classify the meters accordingly.

The loss in the delivery of a service pipe occasioned by the introduction of a Worthington $\frac{5}{8}''$ or a Hesse $\frac{1}{2}''$ meter, is easily calculated.

Suppose for example the $\frac{5}{8}$-inch service pipe to have a length of 100 feet; also 5 elbows each equivalent, in loss of pressure occasioned, to 5 feet of pipe; also one service cock, together with minor obstructions equivalent to 25 feet of pipe. The equivalent length of pipe, of diameter, $d=\frac{5}{8}$ inch, is $l_1=150$ feet $=1800$ inches. After introduction of meter $l_2=(150+30)\times 12=2{,}160$ inches. Weisbach's formula gives

$$v=\sqrt{\frac{2g\,H}{1+\lambda\frac{l}{d}}}$$

wherein H will be the effective head in the main, v the velocity in the service pipe, and λ a coefficient $=.02$ for such velocities as are here involved. If v_1 represents the velocity before, and v_2 after the introduction of the meter

$$\frac{v^2}{v^1}=\sqrt{\frac{d+\lambda\,l_1}{d+\lambda\,l_2}}=\sqrt{\frac{\frac{5}{8}+.02\times 1{,}800}{\frac{5}{8}+.02\times 2{,}160}}=0.914$$

In other words, the meter would occasion, in the case given, a loss: in delivery of service pipe, of about 9%; in effective head back of the faucet, of about $1.00-(0.914)^2=16\%$; in the kinetic energy or capacity for work, of about $1.00-(0.914)^2=24\%$.

Greatest Advisable Rate of Delivery.—When a meter is taxed beyond a certain point it will be seriously damaged. A practical limit in rate of delivery is therefore fixed upon, and this should govern the selection. In addition to this limit in rate of delivery, the corresponding effective head should be given. The allowable effective head in the oscillating piston meters is small, in the rotary piston meters considerably greater, in the velocity meters very high. Where a high head is at hand, and the capacity of the service pipe is great, an oscillating piston meter of large size should be used, whereas it is safe to introduce a comparatively small velocity meter.

Sensitiveness.—The rate of delivery necessary to cause motion of the dial hands, or the greatest quantity per minute which may pass without causing registration, will be taken as an inverse measure of the sensitiveness of the meter.

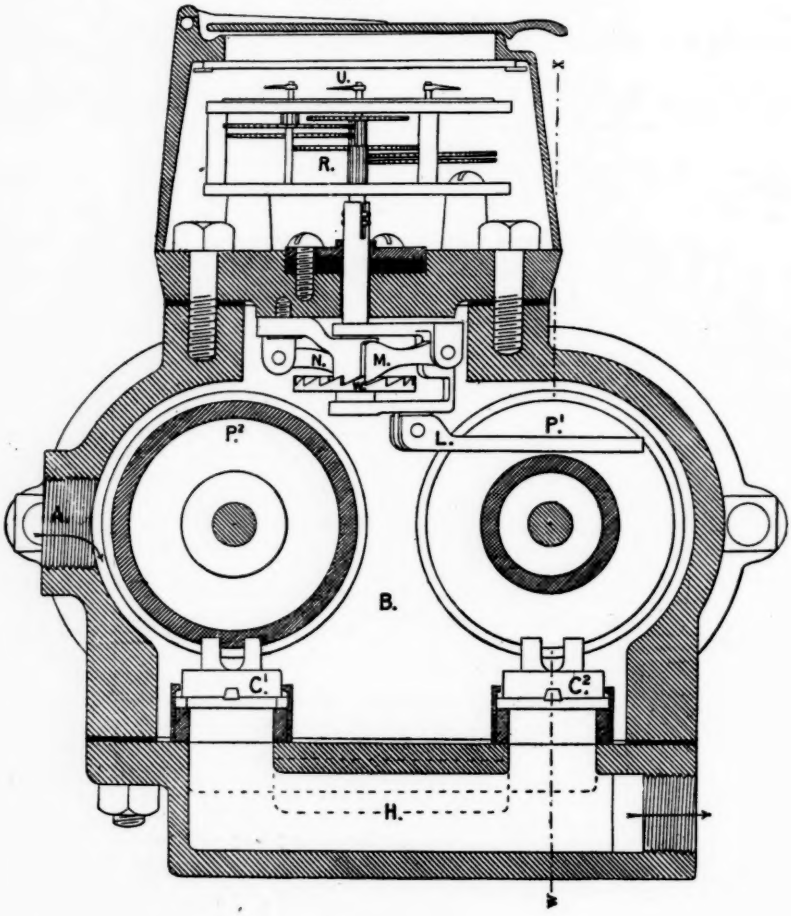
The head lost and accuracy of a meter, are conveniently illustrated by means of curves.

Curves of head lost (see diagram).—These were obtained by plotting on suitable scales, in a rectangular co-ordinate system, the rates of delivery as abscissæ, and the corresponding heads lost as ordinates.

Curves of Registry (see diagrams).—By recording the measurement of the actual quantity delivered, and the reading of the index, under various rates of flow, the data is obtained for plotting a curve which will illustrate the effect of the change in rate of delivery upon the accuracy of registration. The curves given were obtained by plotting the rates of delivery as abscissæ, and the corresponding per cent. registered of the actual quantity delivered as ordinates.

WORTHINGTON METER, 5/8 inch, Scale 1/4.

FIG. 1.



Upon the basis of the considerations enumerated, a comparison of the meters selected has been instituted. A statement of this comparison will be preceded

by a detailed description of each meter concerned.

Piston Meters.—In the piston meters mentioned, the oscillating pistons displace a quantity of water each stroke. The measure of the quantity delivered, is, in the Worthington the number of strokes, in the Kennedy the approximate distance traveled by the piston. The degree of accuracy for the various rates of

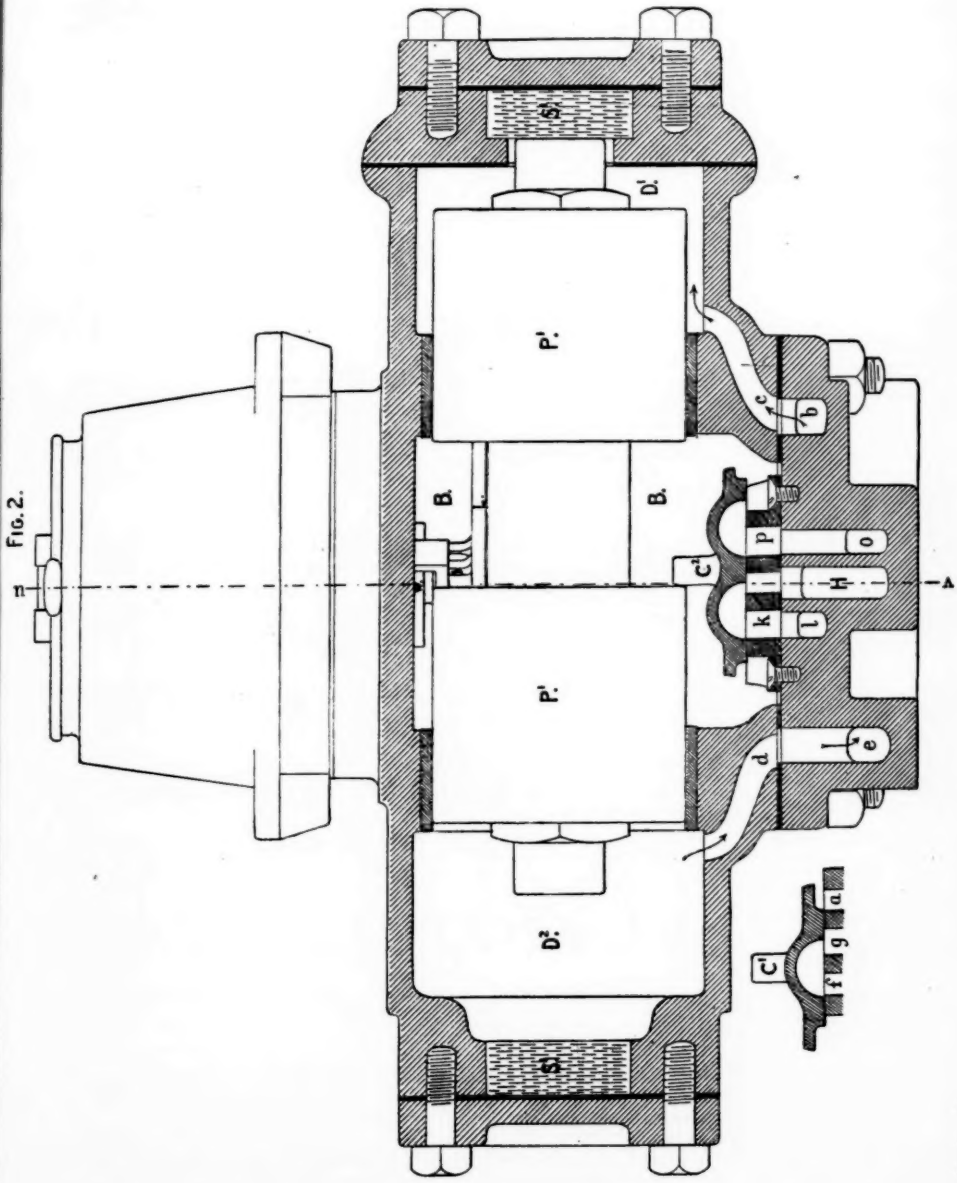
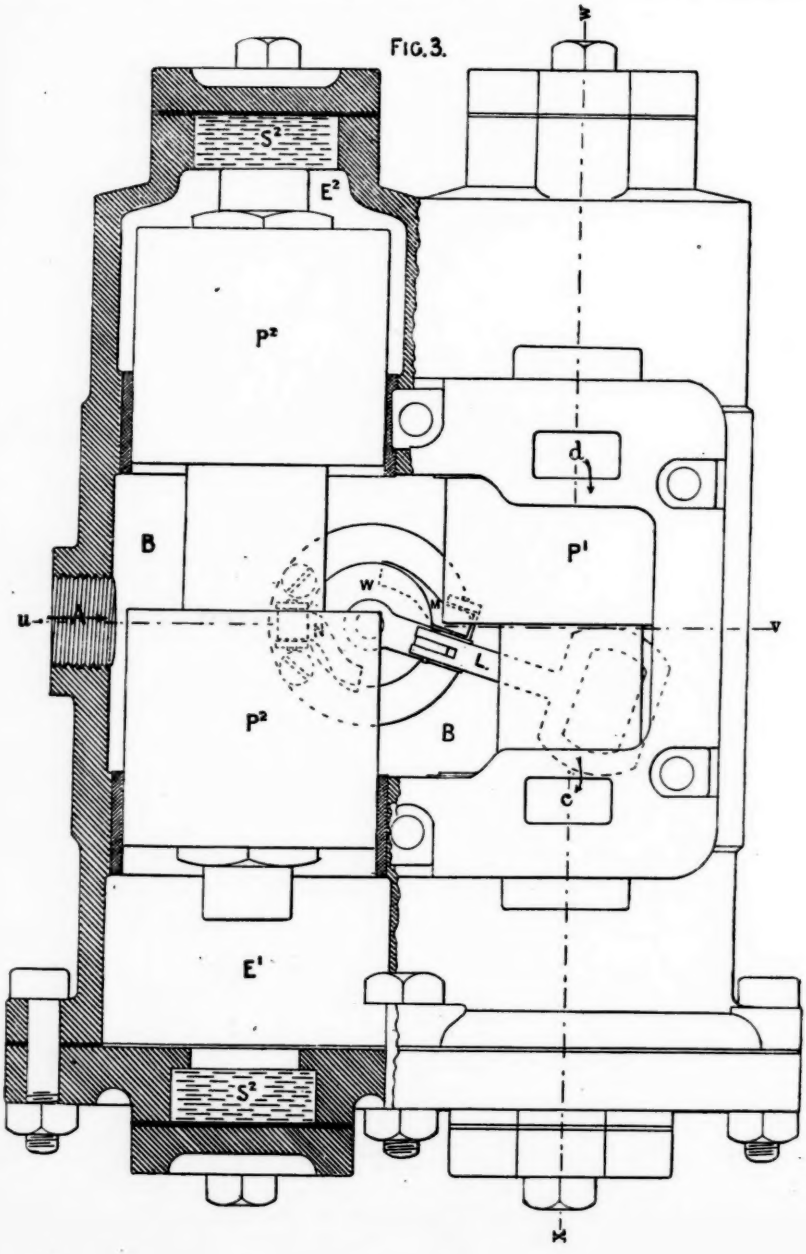


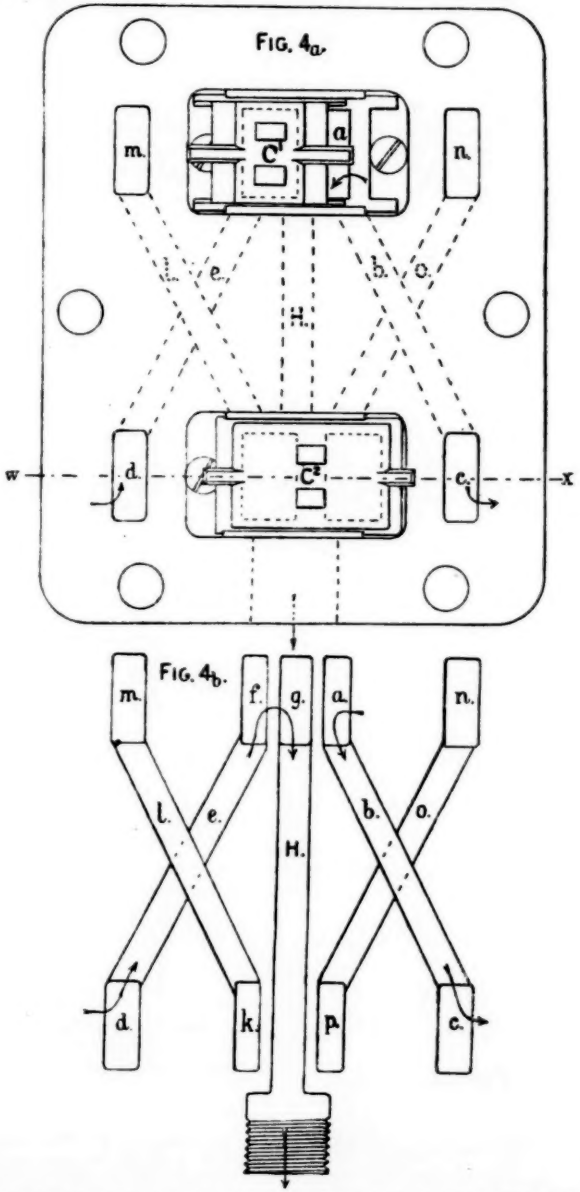
FIG. 2.

delivery, will depend in the Worthington upon the differences in length of stroke, the piston leakage, the action of the valves, &c. In the Kennedy there is a dependency upon, but slight differences in the length of stroke, upon leakage, etc. [These

FIG. 3.



and similar meters are frequently termed *volume* or *positive* meters, in contradistinction to *velocity* or *inferential* meters. There is no general difference in the directness of transmission from the measuring part to the index.



No assumption of advantage is authorized by such a distinction. The approximate volume is registered in either case, and

Description of the Worthington Piston Meter (see Figs. 1, 2, 3, 4_a 4_b)—Letters of reference refer to the same parts in the

different figures. In this meter two piston plungers are closely fitted in parallel cylinders. By means of two slide valves, the water is admitted under pressure into the chamber at one end of each plunger alternatively, while connection is made between the chamber at the other end and the discharge pipe. Thus the piston in moving, displaces the volume escaping through the discharge pipe. The arrangement is such that the strokes of the two plungers alternate, the valve actuated by the one admitting the pressure to the other. The displacement, (area of piston times length of stroke) multiplied by the number of strokes will give approximately the volume of water delivered. The indexing apparatus is arranged to move the dial hands once every fourth stroke, 3 such movements registering $\frac{1}{10}$ cubic foot in the $\frac{5}{8}$-inch meter.

The water enters through opening A into chamber B. In the position of plungers shown, the water then passes through port *a* (of valve C^1), channels *b* and *c* into chamber D^1. Plunger P^1 is moved to the left, forcing the water of chamber D^2 through channels *d*, *e*, ports *f* and *g* into outlet H. In the last third of the stroke, valve C^2 is shifted to the left, establishing communication between chambers B and E^2, through port *k* and channels *l* and *m*—and at the same time connecting chamber E^1 with outlet H through channels *n* and *o* and port *p*. Plunger P^2 is moved to the right, shifting, in the last third of its stroke, valve C^1, and thus establishing communication between chambers B and D^2 through port *f* and channels *e* and *d*.

The pistons are brought to rest at the end of the stroke by rubber seatings S^1, S^2.

Piston P_1 imparts a reciprocating motion to lever L, which, in combination with the movable pawl M, ratchet-wheel W, stationary pawl N, and index gear R, causes the dial hand U to register for each four plunger strokes (single strokes) $\frac{1}{3^{\prime}0}$ of a cubic foot,

Fig. 1 is a section through *uv* (see Figs. 2 and 3).

Fig. 2 is a section through *wx* (see Figs. 1, 2 and 4_a).

Fig. 3 is a view from below with base plate (Fig. 4_a) removed, showing the walls of chamber R partly in section.

Fig. 4_a is a top view of the base plate, showing valves, ports, etc.

Fig. 4_b is a plan of the valve ports, channels and outlet, showing how channel *o* passes under channel *b*, channel *e* under channel *l*, etc.

*Description of the Kennedy Piston Water Meters** (see Figs. 5, 6, 7).—The measuring cylinder (A) forms the base of the meter, and is fitted with a piston (B) made of vulcanite. The piston is made to move perfectly water-tight and almost free from friction, by means of a solid cylindrical ring (C) of pure "Para" rubber, which rolls between the body of the piston and the internal surface of the cylinder. Each end of the cylinder is fitted with an india rubber seating (D), on which the piston will form a water-tight joint, if back pressure should force it to either end of the cylinder; undue pressure is thus prevented from being thrown on the piston roller.

The piston rod (E), after passing through a stuffing box (F) in the cylinder cover (G), is attached to a rack (H) which gears into a pinion (K) fixed on the shaft (L). The shaft is turned in reverse directions, actuating the reversing and indexing gear (M) as the piston moves up and down. The rack is kept in gear and guided in a vertical line by an anti-friction roller, which is carried on a stud projecting from one of the shaft-bearing brackets. The cock-key (P), which directs the water alternately above and below the piston, is placed in the same axial line as the shaft, and is fitted with a duplex lever (Q), which is actuated by a weighted lever (R) carried loosely on the shaft, and caused to fall alternately on each arm of the duplex lever. The weighted lever, after reversing the key, falls on a buffer (S) faced with india rubber, which, yielding before it and traveling in the same curve, gradually brings it to rest.

Fig. 5 is a side section through the center shaft, cock-key, and piston.

Fig. 6 is a front section of cock-key (P) and water passages (U, inlet, and V outlet).

Fig. 7 is a horizontal section through line UV.

The meter is shown in the position of having nearly completed its upward

* Description and figures are taken with but slight changes from the circular of the Kennedy Patent W. M. Co., Kilmarnock, Scotland.

stroke. The water enters at the inlet (U), and is directed by the cock-key down the passage (W) to the bottom of the cylinder, forcing up the piston, which presses the water (which on the previous down-stroke entered above the piston,) up through the passage (X), passing behind passage (V), and is directed by the cock-key into the outlet passage (V). When the piston has moved up a little farther, the bob (weighted lever R) will pass its point of unstable equilibrium and fall on the key arm (arm of duplex lever Q) which it will send down until it is stopped by the buffer box (S). The key will then be at right angles to its position as shown in Fig. 6. The water will then be directed from U down X into the top of the cylinder, forcing the piston down, while the water admitted below during the last stroke is forced up the passage W and out by the outlet V. When the piston has arrived

KENNEDY METER.

FIG. 5.

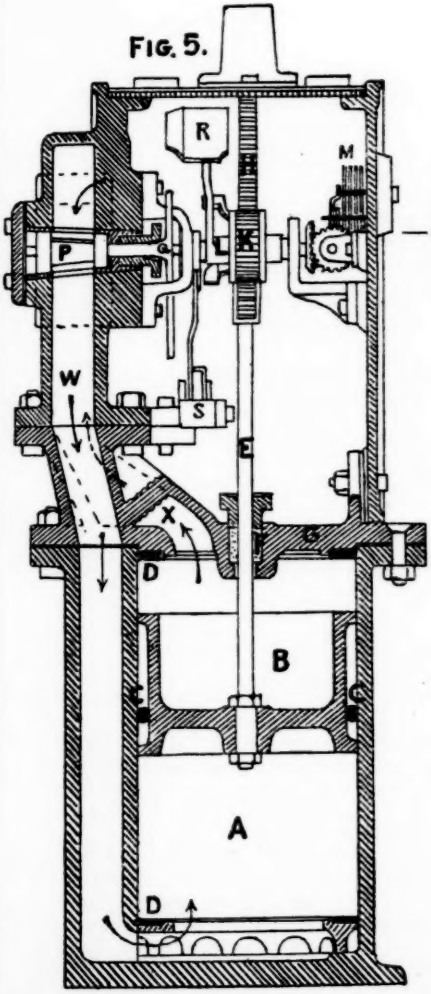


FIG. 6.

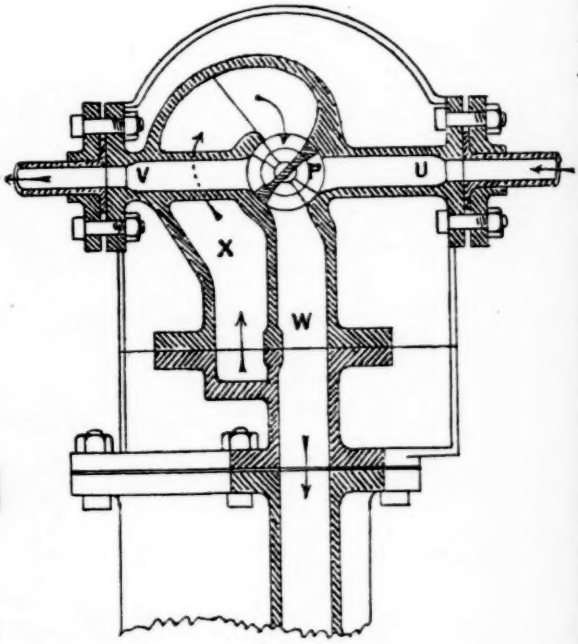
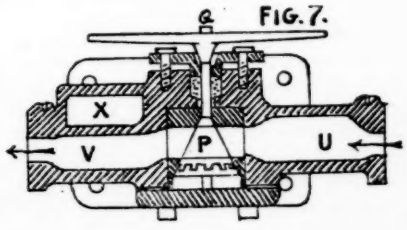


FIG. 7.



near the bottom of the cylinder, the lifter will have lifted the bob from the left side of the buffer-box and raised it to the point of unstable equilibrium; from there it will have fallen on the right hand key-arm, and have brought back the cock-key to its former position, ready to begin another upward stroke.

It is unnecessary to illustrate here the method of converting the reciprocating motion of the shaft (L) into the circular motion (in one direction) of the index wheels (M), and thus causing to be registered a quantity approximately proportional to the distance traveled by the piston.*

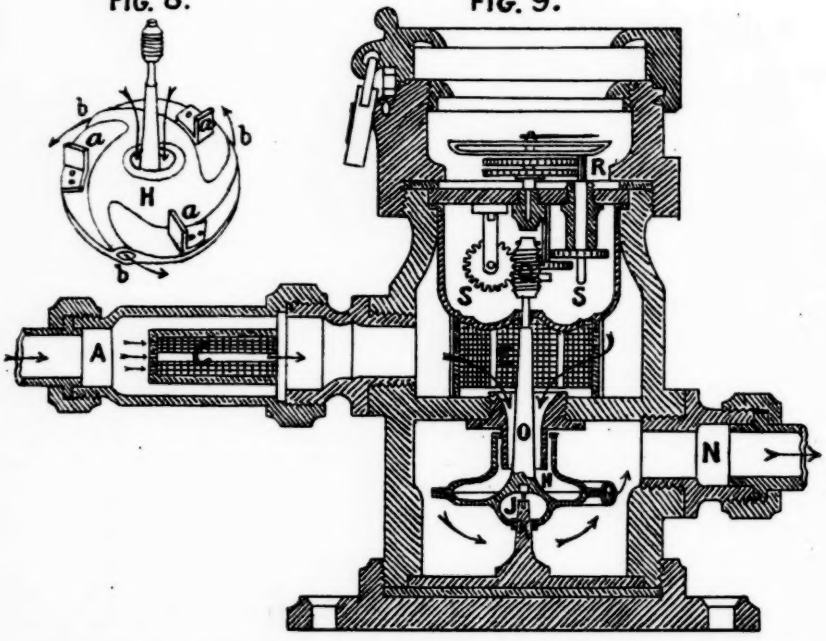
VELOCITY METERS.—In the velocity meters of the Siemens system a small wheel is driven by the passing water, and the number of revolutions is the measure of the quantity delivered. The frictional resistance, offered by the journals of the wheel spindle and the registering apparatus, cause important modifications of the velocity of the wheel. The Hesse meter practically overcomes the objectionable influence of this resistance, but it will be shown that, even if it could be wholly avoided, perfect accuracy of registration would not thereby be effected.

*Description of the "English" Siemens Velocity Water Meter** (see Figs. 8, 9).—Of the Siemens system there are two important forms, the one manufactured by Guest & Chrimes of Rotherham, England, and the other by Siemens & Halske of Berlin. The former will be termed the "English" Siemens, and the latter the "German" Siemens.

ENGLISH SIEMENS METER

FIG. 8.

FIG. 9.



It will be seen from the figure of the English Siemens meter, that the water passes, as indicated by the arrows, from the inlet pipe through a funnel, into a

* A ratchet is interposed between the pinion and the registering gear, and the degree of approximation in indicating the "length of piston travel" depends upon the number of teeth in the ratchet.

* Description, in the main, and figures taken from the circular of Guest & Chrimes.

small reaction wheel, or Barker's mill (H), (constituting the measuring drum,) causing it to revolve. The water then passes on to the outlet pipe. The motion imparted to the measuring drum is communicated to the index, and thus a quantity proportional to the number of revolutions of the drum, registered.

Fig. 8 is a perspective view of the drum or measuring medium (H), showing the adjusting or regulating vanes *a a a*, and curved water ways *b b b*.

for the purpose of lubricating and protecting the dial wheels from the action of the water, etc.

*Description of the "German" Siemens Velocity Water Meter** (see Figs. 10, 11). —This meter differs from the "English" Siemens in so far as the motor is concerned, a small pressure wheel taking the place of the reaction wheel.

The water having entered the meter through the inlet pipe U, passes through the openings *a a a a*, in the brass casing

GERMAN SIEMENS METER

FIG. 10.

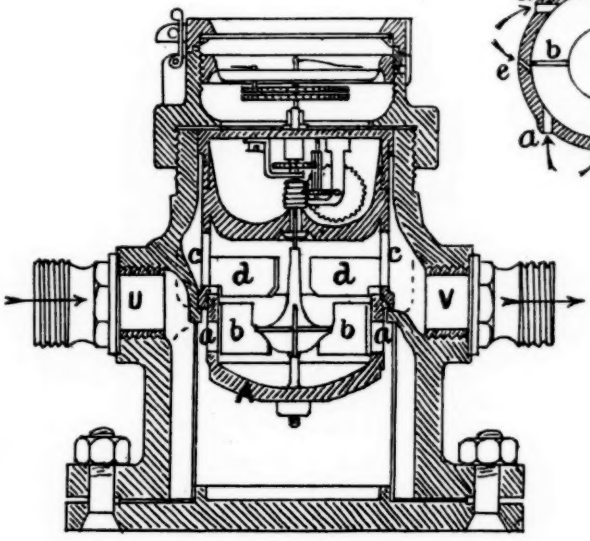


FIG. 11.

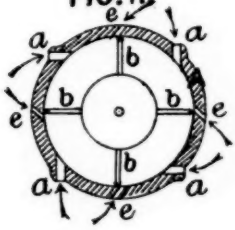


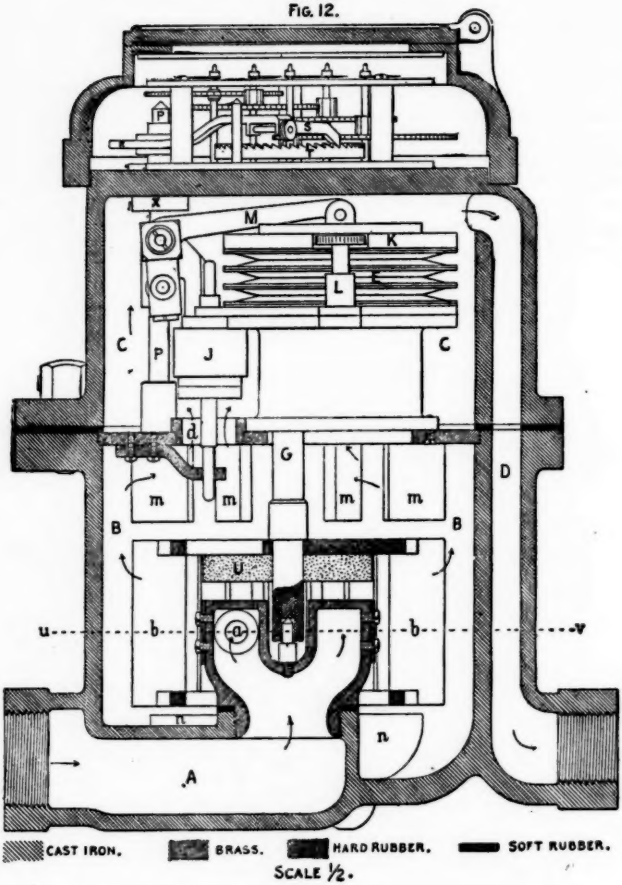
Fig. 9 is a section of the meter, filter and unions complete. A is the inlet. C and E are filters for the purpose of preventing foreign substances from passing into the drum H. The motion of this drum is retarded and suitably regulated by the vanes *a a a*. J is an oil-box for the purpose of lubricating the spindle K. N is the outlet. O is the spindle of the drum, with screw Q attached for the purpose of giving motion to the wheels of the dial work R. S S is an oil chamber A, and coming in contact with the buckets *b b b b*, imparts motion to the wheel. The water then escapes through openings *c c*, and finally discharges into the outlet pipe V.

* The figures are taken from a valuable article, on the subject of water meters, in the German "*Civilingenieur*" of the year 1875, by B. Salbach, Kgl. Baurath at Dresden. At the instigation of the City Council of Dresden, an exhaustive set of tests were made of twelve "meters of the most modern construction"—among these the Kennedy, the "English" and the "German" Siemens. Further reference will be made to this article.

HESSE METER

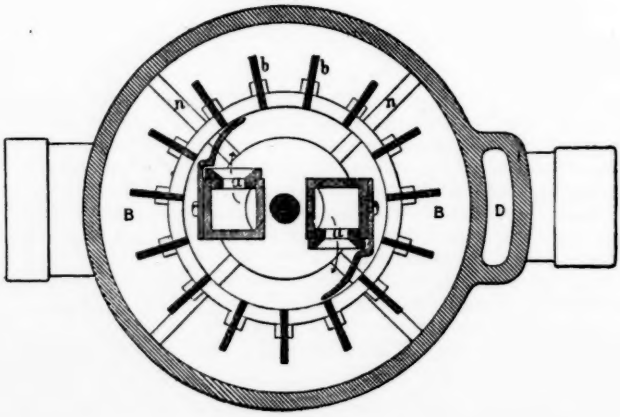
½ INCH.

FIG. 12.



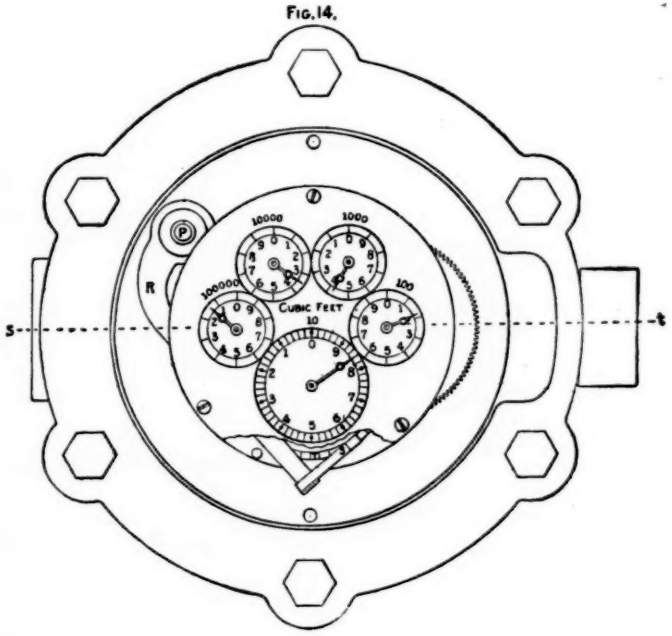
SCALE ½.

FIG. 13.



The manner in which the motion is imparted to the wheel is transmitted to the index, is the same as in the "English" Siemens. In order to keep out the coarse sediment, the water is made to pass through a screen before entering the meter. For the purpose of regulating the velocity of the wheel, four small openings *eeee* are bored into casing A, in a direction opposed to the motion of the wheel; and by closing or enlarging these, the velocity of the wheel may be increased or reduced.

FIG. 14.



The stationary ribs *d d* counteract in part the tendency of the water to rotate.

Description of the Hesse Velocity Water Meter (see Figs. 12, 13, 14, 15, 16, 17, 18).—The water from the inlet pipe enters channel A (Fig. 12), passes through openings *a a* (Figs. 12, 13), and striking the buckets *b b* (Figs. 12, 13), imparts motion to the measuring wheel—a pressure wheel similar in character to that of the "German" Siemens. The water passes then from the wheel chamber B into chamber C, mainly through valve opening *d* (Fig. 12), and in part through chamber *e*, opening *f*, chamber *g*, and conical tube *h* (Figs. 16, 17), and is finally discharged through chamber D into the outlet pipe.

The motion of the measuring wheel is transmitted to the worm wheel H (Figs. 16, 17), by means of the endless screw F (Fig. 16), which is attached to the upper end of the wheel spindle G (Figs. 12, 16). This worm wheel, in revolving, interrupts intermittently the direct flow of that portion of the water which passes through chamber *g*. In the position of the worm wheel shown in (Fig. 16), the solid arm of the wheel (the cause of this interruption) is just passing the openings *f* and *h*, hence direct flow through these openings is just beginning. During the interval of direct flow the action is comparable to that of the jet pump, causing the pressure in chamber *g* to fall below that in chamber C. The interruption of the direct flow causes the pressure to rise above that in chamber C.

The alternating high and low pressures in chamber *g*, thus induced by the slow rotation of the worm wheel, cause the cap K of the bellows-like rubber dia-

phragm E (Figs. 12, 16, 17) to rise and fall accordingly. The number of such pulsations or strokes is directly proportional to the number of rotations of the measuring wheel. The length of the stroke is limited by the heads of set screws LL (Figs. 12, 16, 17).

This reciprocating motion of the cap K is transmitted and converted into the circular motion of the gear wheels of the index, through lever M, rock-shaft N, shaft P, lever R, pawl S, and ratchet wheel T (Figs. 12, 14, 15).

The dial hands are thus made to register a quantity, which is directly proportional to the number of revolutions of the measuring wheel. The measuring wheel is made of hard rubber of specific gravity 1.2, and with the cork attachment (U*) has the same weight as an equal volume of water. There is then so little pressure upon the journals of the spindle G, that the frictional resistance offered is exceedingly small. The worm wheel H rests loosely in its bearings, offering but little resistance to rotation. Since in 38 revolutions of the measuring wheel, but one revolution is given to the worm wheel, the work and hence the effective resistance is minute. The frictional resistance due to the periodic pressure upon the journals of the worm wheel, as the arm passes opening *f*, was found by experiment to be very small.

When the meter is delivering water at rates above three or four gallons per minute, the valve J is lifted, but the difference of pressures in chambers B and C is far greater than that needed to operate the bellows. When the rate of delivery is small, the valve is seated, and the entire quantity is forced through

FIG. 15.

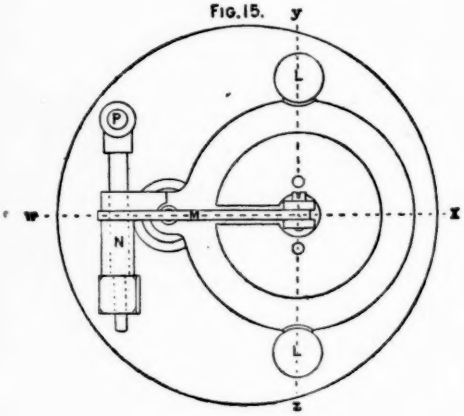


FIG. 16.

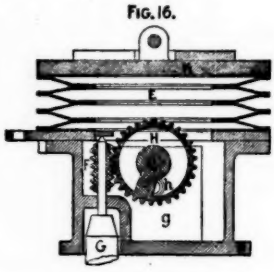


FIG. 17.

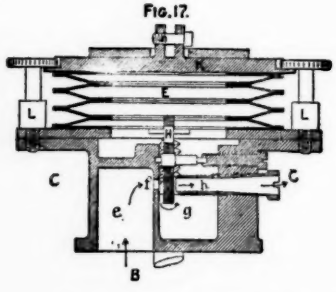
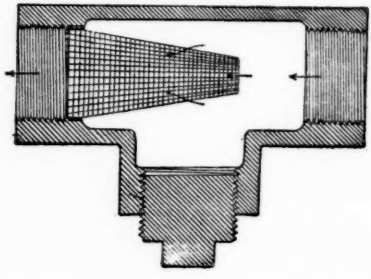


FIG. 18.



* The cork attachment is unnecessary, as the weight of the wheel in water is sufficiently small without it.

chamber *g*, insuring the action of the bellows.

The alternate rise and fall of pressure in chamber *g*, furnish an abundant surplus of power to provide against undue resistance in the stuffing box X (Fig. 12), and all differences due to the character of the workmanship, and to wear or corrosion of the parts of the registering apparatus.

The measuring wheel does not supply the power expended in moving the registering apparatus, hence the unavoidable changes in the latter do not affect the accuracy of the meter. This points to the distinctive feature of the Hesse meter.

m, *m*, and *n*, *n* (Figs. 12, 13) are stationary ribs provided for the purpose of checking in part the rotation of the water in chamber B, and offering additional resistance to the motion of the wheel. Such resistance diminishes the detrimental influence of the solid friction, and causes almost immediate stoppage of the wheel in case the water is suddenly shut off.

The meter tested is provided with connections for $\frac{1}{2}$ inch pipe. Openings *aa* have $\frac{9}{32}$ inch diameter. Valve opening *d* has $\frac{5}{8}$ inch diameter. Weight of valve J is 0.16 lb. Entire weight of meter is 21.4 lbs.

Fig. 12 is a vertical section through *st* (see Fig. 14).

Fig. 13 is a horizontal section through *uv* (see Fig. 12).

Fig. 14 is a top view of the meter with the dial box removed, showing the dials, etc.

Fig. 15 is a top view of that portion of the registering apparatus contained in chamber C (see Fig. 12).

Fig. 16 is a vertical section of the bellows-like diaphragm, etc., taken through *wx* (see Fig. 15).

Fig. 17 is another vertical section of the same through *yz* (see Fig. 15).

Fig. 18 is a section of the screen or filter which is interposed between the meter and the inlet pipe.

The material used in constructing the meter is shown by the manner of shading the sections. It may be found advantageous to make a different selection for some of the parts. The meter will not serve for the delivery of hot water without radical changes in the material.

The Kennedy and the Siemens Curves (see diagrams) were obtained from the experiments of Mr. Salbach (see foot note), who used such curves as a means of comparison.

The volume of water delivered was measured in an accurately constructed tank. The loss of head was given by the difference of the readings of two large quicksilver manometers, the one communicating with the inlet, and the other with the outlet pipe immediately adjacent to the meter.

Tests were made under mean heads* of about 45 and 150 feet. The change of mean head had no material effect upon the curves of registry of these meters, excepting in the case of the "German" Siemens meter II, which gave better results under the greater head, and even this was doubtless due to cleaning of the meter in the interval. The effect upon the curves of head lost was not important, and was probably due, as Mr. Salbach says, (mainly) to some imperfections in the manometers when under low pressure, The curves of registry were plotted from the tests made under the lower mean head, the curve from tests under the higher mean head being added for the "German" Siemens meter II—II_a lower, II_b higher mean head. The curves of head lost were plotted from the tests under the higher mean head.

The Worthington B, C *and* D curves of registry were plotted from the results of experiments conducted by Prof. Hesse, as chairman of a committee appointed by the Board of Managers the Twelfth Industrial Exhibition of the Mechanics' Institute 1878 (published in report). Meter B had never been in use, C had been in use 3 months, D 8 months. A number of others were tested showing the effect of wear, etc.

The Hesse and the Worthington A curves were plotted from the results of a set of tests conducted by the writer, with the assistance of Mr. H. Dikeman, a student of engineering in the University of California.

The Hesse meter tested, forms a part of some experimental apparatus in the Mechanical Laboratory.

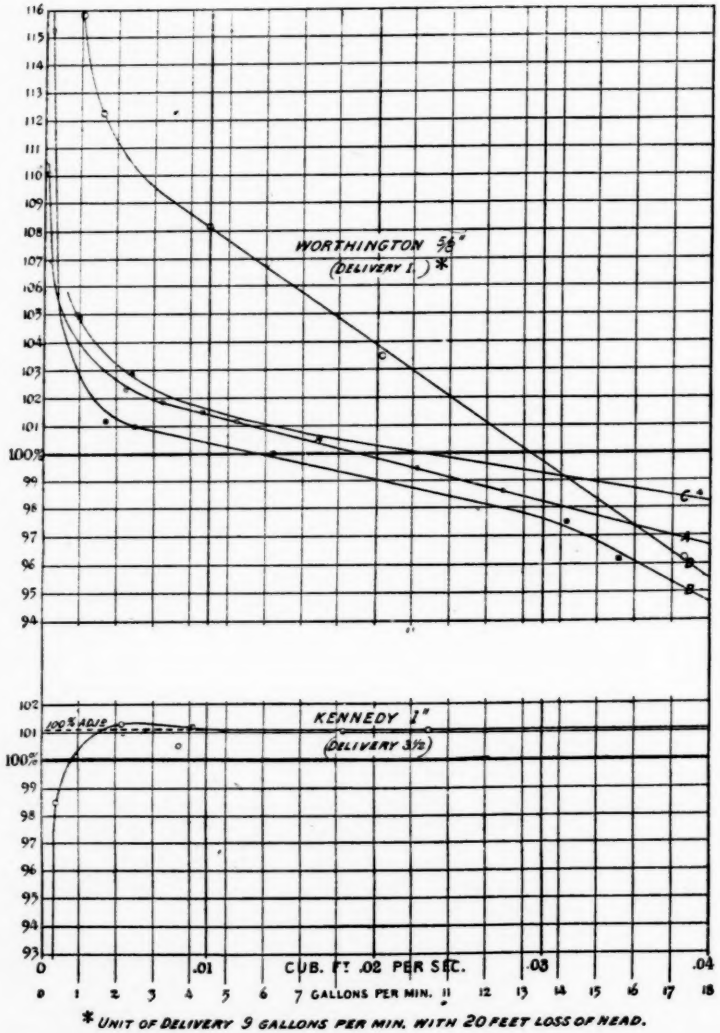
The Worthington A is a $\frac{5}{8}$-inch meter which was specially selected by Mr. Pur-

* It is presumed that by "mean head" is meant the average head in the inlet pipe.

cell of the Oakland Water Co. to serve as a test meter.

The quantity of water delivered was weighed to $\frac{1}{10}$ lb., and the pressure measured by means of a sensitive gauge described in the *Mining and Scientific Press* of September 2, 1882, also in *Bulletin No. 1* of the College of Mechanics. With this gauge the heads could easily be measured to $\frac{1}{10}$ of a foot. The time was observed only to single seconds. The results of these tests are tabulated below. The diameters of the inlet and outlet pipes were the same at the points where connected with the pressure gauge, so that it was unnecessary to make allowance for the velocity heads at these points in order to obtain the effective difference of heads. The temperature of the water varied 2° F., averaging 55° F.

CURVES OF REGISTRY

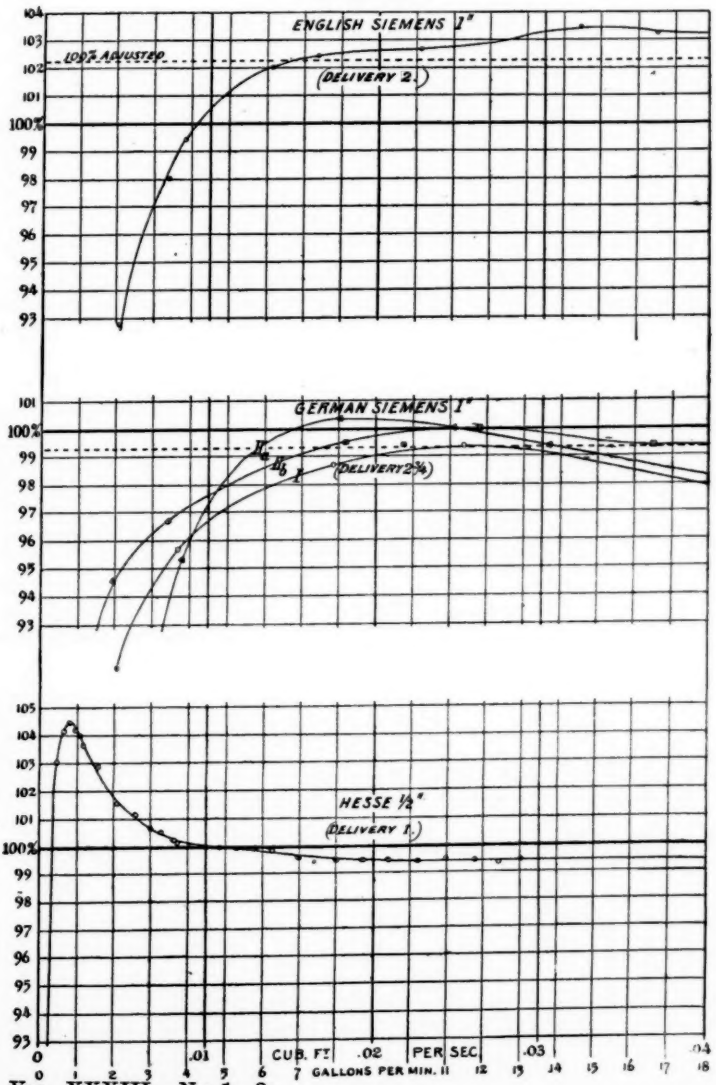


* UNIT OF DELIVERY 9 GALLONS PER MIN. WITH 20 FEET LOSS OF HEAD.

The possible error in these tests, it is thought, may be safely taken at 1 per cent. in the rate of delivery, at $\frac{1}{4}$ per cent. in the ratio of registered to actual delivery, and at one foot in head lost at high rates, and $\frac{2}{10}$ foot at low rates.

The Hesse meter, experimented with, had previously been subjected to various tests by the Oakland Water Co., and had delivered during four months, 62,000 cubic feet (in great part at the rate of $12\frac{1}{2}$ gallons per minute), without being in the least damaged. This is a greater quantity than would be drawn in 5 years in the average service. However, it must be borne in mind that this test involved the important element of time only to a small extent.

CURVES OF REGISTRY



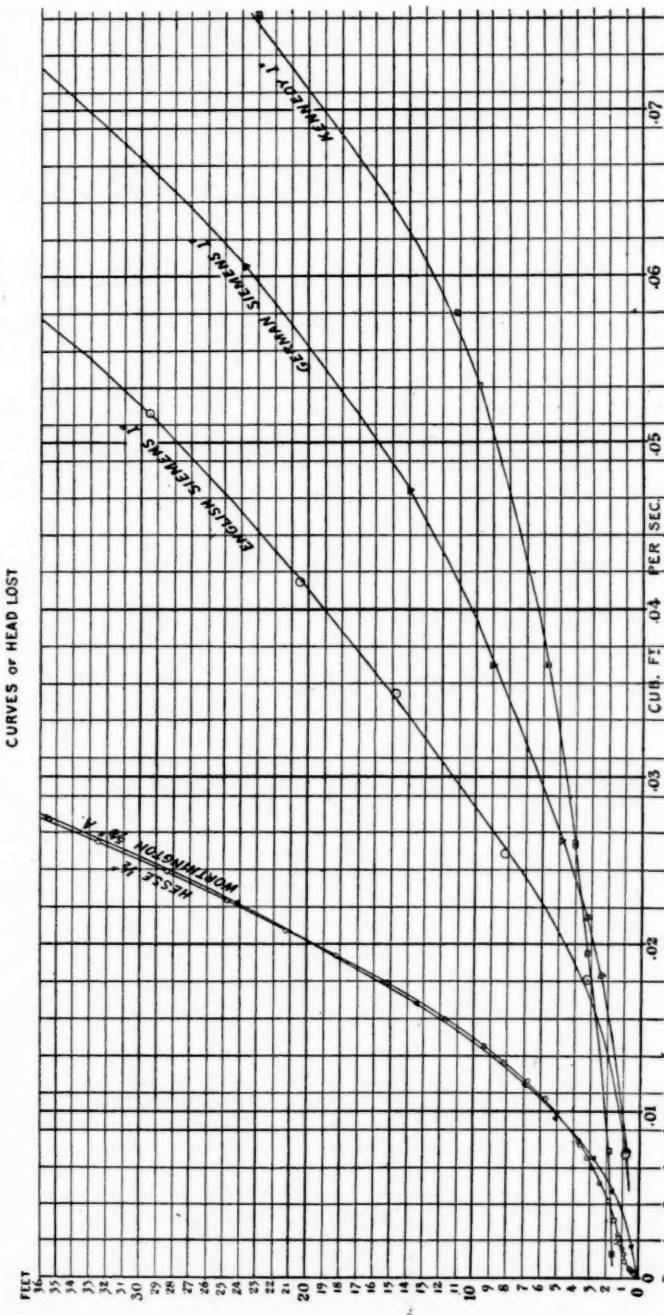
TESTS OF THE ACCURACY AND DELIVERY OF THE HESSE ONE-HALF INCH METER.

No. of Test.	Hydraulic Heads in Feet. Inlet H.	Hydraulic Heads in Feet. Outlet h.	Time in Sec's.	Weight in lbs. avoir-dupois G.	Cubic Feet. Actual $\frac{G}{62.4}$	Cubic Feet. Registered.	Rate of Delivery. Cubic ft. per sec.	Rate of Delivery. Gals. per min.	Head lost in Feet, H-h.	Ratio of Regist. to Actual Volume in per cent.
1	——	——	——	——	——	—	.00015	.07	——	——
2	59.85	59.40	1308	31.3	0.502	0.4	.00038	.17	.45	79.7
3	59.50	59.00	2543	72.2	1.157	1.0	.00046	.21	.50	86.4
4	59.00	58.15	3660	218.0	3.494	3.6	.00096	.43	.85	103.0
5	59 40	58.55	1392	119 8	1.920	2.0	.00138	.62	.85	104.2
6	50.40	58.45	1102	119.5	1.915	2.0	.00174	.78	.95	104.4
7	50.40	58.30	915	119.8	1.920	2.0	.00210	.94	1.10	104.2
8	59.20	58.05	802	120.0	1.923	2.0	.00240	1.08	1 15	104.0
9	59.10	57.90	1125	180.6	2.894	3.0	.00257	1.15	1.20	103.7
10	59.0	57.5	840	182.0	2.917	3.0	.00347	1.56	1.5	102.9
11	58.8	56.9	641	184.3	2.954	3.0	.00461	2.07	1.9	101.6
12	57.1	54.7	524	185.0	2.965	3.0	.00566	2.54	2.4	101.1
13	56.8	53.9	452	186.0	2.981	3.0	.00660	2.96	2 9	100.6
14	56.5	53.3	441	198.6	3.183	3 2	.00722	3.24	3.2	100.5
15	56.3	52.7	375	186.8	2.994	3.0	.00798	3.58	3.6	100.2
16	55.8	52.1	365	187.0	2.997	3.0	.00821	3.69	3.7	100.1
17	55.9	50.9	304	187.3	3.002	3.0	.00987	4.43	5.0	100.0
18	55.6	49.9	563	374.6	6.003	6.0	.01066	4.79	5.7	100.0
19	55.2	48.4	507	374.7	6 005	6.0	.01184	5.32	6.8	99.9
20	54.7	46.5	465	374.7	6.005	6.0	.01291	5.80	8.2	99.9
21	54.3	44.9	432	375.0	6 010	6.0	.01391	6.24	9 4	99.8
22	55.0	45.8	434	375.0	6.010	6.0	.01386	6.22	9.2	99.8
23	54.5	42.8	390	376.0	6.026	6.0	.01545	6.94	11.7	99.6
24	53.5	38.3	340	376.4	6.032	6.0	.01774	7.97	15.2	99 5
25	52.8	34 5	312	376.5	6.034	6 0	.01934	8 68	18.3	99.4
26	50.7	29.4	290	376.5	6.034	6.0	.02081	9.34	21.3	99.4
27	49.7	24.9	267	376.7	6.037	6.0	.02261	10.15	24.8	99.4
28	49.3	20.9	256	388.8	6.232	6.2	.02434	10.93	28.4	99.5
29	47.6	15.1	231	376.7	6.037	6.0	.02613	11.73	32.5	99.4
30	46 5	11.1	220	377.0	6.042	6 0	.02746	12.33	35 4	99.3
31	45.7	6.8	210	376.7	6.037	6.0	.02875	12.91	38.9	99.4

In test No. 1 the limit was reached.

TESTS OF THE ACCURACY AND DELIVERY OF THE WORTHINGTON FIVE-EIGHTHS INCH METER.
(A) No. 26,737.

No. of Test.	Hydraulic Heads in Feet. Inlet H.	Hydraulic Heads in Feet. Outlet h	Time in Sec's.	Weight in lbs. avoir-dupois G.	Cubic Feet. Actual $\frac{G}{62.4}$	Cubic Feet. Registered.	Rate of Delivery. Cubic ft. per sec.	Rate of Delivery. Gals. per min.	Head lost in Feet, H-h.	Ratio of Regist. to Actual Volume in per cent.
1	——	——	——	——	——	——	.00015	.07	——	——
2	59.00	58.85	1622	17.0	.2724	.30	.00017	.08	.15	110.1
3	59.00	58.80	640	15.5	.2484	.27	.00039	.18	.20	107.0
4	58.85	58.40	492	59.4	.9519	1.00	00193	.87	.45	105.1
5	58.65	57.00	379	122.0	1.9551	2.00	.00516	2.32	1.65	102.3
6	58.15	55.40	272	122.5	1 9631	2.00	.00722	3 24	2.75	101.9
7	57.30	52 20	308	184.4	2.9551	3.00	.00960	4.31	5.10	101.5
8	56.5	49.5	255	185.0	2.9647	3.00	.01163	5.22	7.00	101.2
9	53.8	40.4	302	310 7	4.9791	5 00	01649	7.40	13.40	100.4
10	49.1	24.9	224	313.8	5.0288	5.00	.02245	10.08	24.20	99.4
11	43.7	8.1	184	316.3	5.0689	5.00	.02755	12.37	35.60	98.6


CURVES OF HEAD LOST
FEET
CUB. FT. PER SEC.
.01
.02
.03
.04
.05
.06
.07
16 GALLONS PER MIN.
KENNEDY 1"
GERMAN SIEMENS 1"
ENGLISH SIEMENS 1"
HESSE 1"
WORTHINGTON 5/8" A

DISCUSSION OF THE CURVES OF HEAD LOST.—These are approximately parabolic, and may be represented roughly by the equation $H-h=A+BQ^2$, wherein Q is the quantity delivered in cubic feet per second, A and B constants. In the Worthington $\frac{5}{8}$-inch A=0.4, B=46,000.

These curves simply serve the purpose of determining the deliveries of the several meters, prior to making comparisons of sensitiveness, cost, &c. By following the 20 feet line it will be seen that with this loss of head the Worthington $\frac{5}{8}$-inch delivers 9.1 gallons per minute, the Hesse $\frac{1}{2}$-inch 9.1; the English Siemens 1 inch 18.5; the German Siemens 1 inch 25.1; the Kennedy 1 inch 32.0. If then the delivery of the Worthington $\frac{5}{8}$ inch, under effective head of twenty feet,* is adopted as unit, we have: Worthington $\frac{5}{8}$"....1, Hesse $\frac{1}{2}$" ...1. English Siemens 1"....2, German Siemens 1"....$2\frac{3}{4}$, Kennedy 1"....$3\frac{1}{2}$.

It would have been of great advantage in making the comparisons which follow, could the sizes of the several meters have been so selected as to make the deliveries the same under the same effective head.

DISCUSSION OF THE CURVES OF REGISTRY.—The notable properties of these curves are to be found in the degree of approximation to parallelism of the horizontal sweep to the axis of abscissæ, and in the proximity of the vertical sweep to the axis of ordinates. The former furnishes the true criterion for estimating the degree of accuracy which may be reached by adjustment, the latter indicates the degree of sensitiveness of the meter.

These curves may be shifted up or down, or the curves remaining stationary, the 100% lines may be so shifted by a simple adjustment of the meter. This may be effected, in each of the meters, by changing the number of teeth in one or more of the gear wheels leading to the index, since this number determines the ratio of the movements of the dial hands to the movements of the pistons in the piston meters, and of the measuring wheels in the velocity meters.

Such a change may be effected also, though to a smaller extent, as follows:

In the Worthington, by adjustment of the length of stroke.

In the English Siemens, by change of the regulating vanes *a a a*.

In the German Siemens, by increase of the openings *a a a a* or *e e e e*, or by change of the buckets.

In the Hesse, by change of the number of teeth in worm wheel H, or by increase in size of openings *a a*, or by change of the buckets or stationary ribs.

An inspection of the curves will bring out some marked features.

The *Worthington curve*, for quantities above three gallons per minute, becomes practically a right line, strongly inclined to the axis of abscissæ, showing at low rates too great, and at high rates too small a registry. This is doubtless due, in the main, to the differences in length of stroke. This stroke is on the average a little above two inches. A $\frac{5}{8}$ inch rubber seating is compressed at each end of the stroke by an amount, increasing with the momentum or with the velocity of the piston, hence with the rate of delivery. If the difference in the magnitude of this compression, between rates of 3 and 15 gallons per minute, is $\frac{1}{16}$ inch each seating, there results $\frac{1}{8}$ inch difference in length of stroke. The meter registers the number of strokes, hence, if adjusted to register correctly at rate of 3 gallons, it will register about $\frac{1}{16}=6\%$ too little at rate of 15 gallons per minute.

As the rate becomes less than 3 gallons per minute, the diminution in length of stroke is more marked.

The *Kennedy curve*, when compared with the Worthington, shows the advantage of registering the approximate distance traveled by the piston, in place of the number of strokes, the main sweep being practically parallel to the axis of abscissæ. By proper adjustment, *i. e.*, by shifting the 100% line upward 1.05% (see dotted line), this curve is made almost perfect.

The *Siemens curves* were improved by adjustment (see dotted lines). They show inferiority in point of sensitiveness. This is due to the resistances of solid friction opposing the motion of the measuring wheels.

The *Hesse curve* shows a favorable adjustment, and a degree of sensitiveness nearly equal to that of the best piston meters. The effect of solid friction is not observable for quantities exceeding one gallon per minute. The curve, following

* The velocity head in the $\frac{5}{8}$ inch outlet is small, and is therefore neglected.

the law of combined fluid pressure and resistance, rises rapidly for quantities less than four gallons per minute. If there were absolutely no solid frictional resistance, the curve would mount to a great height as the quantity approached zero—see considerations which led to the adoption of the form of measuring wheel.

Comparison. — The meters described will be compared with reference to the considerations enumerated.

1st. The accuracy will primarily be compared by means of the adjusted curves, and without reference to permanency. Such comparison shows the Kennedy curve to be without doubt the best; then follow in order the Hesse, the Worthington A and B, the German Siemens, the English Siemens, the Worthington D.

2d. The necessity of special adjustment is greater in the Worthington than in the Kennedy, in the Siemens than in the Hesse. A close comparison is difficult without the experience of the manufacturers; it is apparent, however, from the curve, that even the Kennedy requires a special adjustment if great accuracy is sought.

3d. The difficulty of special adjustment is greater than it should be, in each of the meters excepting the Worthington. Provisions should be made for these adjustments outside of the casing. In the Hesse meter, for instance, this might be effected by suitable provision for shifting of one or more of the stationary ribs. The Worthington is easily adjusted by tightening or loosening the screws of the cap, covering one of the rubber seatings.

4th. A certain degree of sensitiveness is important. This is apparent from the fact that one gallon in three minutes can be made to supply a household by use of a small storage tank. The Kennedy 1″ will register a gallon in from 20 to 30 minutes; the Worthington $\frac{5}{8}$″ and the Hesse $\frac{1}{2}$″, a gallon in 15 minutes; the two one inch Siemens meters a gallon in from 1 to $1\frac{1}{2}$ minute. A direct comparison of these figures would not be fair to the Siemens meters, as the deliveries (under given head) of the sizes tested were greater than those of the Worthington and the Hesse. However, it is safe to say that the Siemens meters are much inferior in point of sensitiveness. The wear of the Worthington piston will cause deterioration in this respect, unless the meter is judiciously used.

The sensitiveness of the Hesse meter may be greatly increased, but at the expense of the accuracy at small rates of delivery. However, a rate of one gallon in 15 minutes or 96 gallons in 24 hours, is about the minimum rate admitted in Providence, R. I., and only $\frac{1}{4}$ of the quantity passed in the average service. Such a degree of sensitiveness makes theft out of the question.

5th. With respect to permanency of sensitiveness and accuracy, it is confidently thought that the Hesse meter will stand foremost under a wide variation of wear, etc.

There is no leakage due to wear of valves and piston, no alteration due to change of friction by wear, rusting, or oiling of the registering apparatus. The only parts which might be regarded as sensitive in this respect, are the circular openings $a\,a$; but as these are made of hard rubber, no rusting can take place, and any tendency towards diminution in size of these openings, by deposition of sediment, is overcome by the rapid flow of water. Little of the wear which may take place in the meter is of a nature to effect its curve of registry.

It is probable that the Kennedy curve is reasonably permanent.

The effect of wear, upon the Worthington curve, is plainly shown by comparison of curves B, C and D. It must be remarked, however, that it is unfair to charge against this meter a deterioration which appears to be due to over taxation. The manufacturing company calls special attention to the fact that their $\frac{5}{8}$ inch meter should not be taxed with a delivery greater than $7\frac{1}{2}$ gallons per minute. This corresponds to an effective head of about 16 feet. In San Francisco, where the hydrostatic head runs up to two hundred and fifty feet and more, it does not seem likely that the $\frac{5}{8}$″ Worthington is large enough for the average service.

That the Siemens curves are not particularly permanent is plain from the fact already mentioned, viz.: that the accuracy and sensitiveness depend upon the magnitude of the frictional resistance of the indicating apparatus, and this will vary constantly with rusting, wear, etc. Mr.

Salbach, who has given the German Siemens meter careful consideration, says it is capable of giving good results in every respect when new, but after a while the meter will deteriorate in so far as the accuracy is concerned in the measurement of quantities at small rate of flow. "The main cause," he further says, "is the oil which is contained in the first chamber above the wheel, and which in time adheres to the gear wheels. A further detrimental effect is produced by freezing or thickening of the oil in case the temperature sinks to 2 or 3° C. From these facts it is plain that the oil chamber is a bad feature of this meter, and one that there should be an energetic effort made to overcome." This has been effected in the Hesse Meter.

6th. The liability to obstruction was not tested in the Worthington and Hesse meters, as similar data was wanting in connection with the others. A suitable screen (see Figs. 9 and 18) should be provided for each meter to keep out the coarser obstructions, such as leaves, straw, chips of wood, wads of oakum, etc., which are easily withheld. The liability to obstruction is said to be a weak feature of some of the rotary piston meters, but not of the oscillating. To be sure a sandy deposit in the measuring cylinder will cause rapid wear in the Worthington, and a certain resistance to free rolling of the rubber ring in the Kennedy; but with reasonably clear water no serious difficulty seems likely to occur if the coarser obstructions are screened, and thus wedging of valves prevented. The sandy or muddy sediment is probably less detrimental to the velocity meters when properly constructed. It is suggested that the cylindrical wheel chamber in Hesse's meter should be extended a few inches in length and provided with a waste cock at the bottom, for convenient discharge of accumulated sediment, in case it should be used for the measurement of muddy water.

7th. The greatest advisable rate of delivery is least in the Worthington, and most in the velocity meters. As already stated the Worthington is not guaranteed for an effective head exceeding 16 or 20 feet, corresponding to a delivery of 7½ gallons per minute by the $\frac{5}{8}''$, 15 gallons by the $\frac{3}{4}''$, etc. The safe limit of effective head in the Kennedy is, according to the manufacturer's statement, about 60 feet, the $\frac{3}{4}''$ delivering 20 gallons per minute, the $\frac{1}{2}''$ 30 gallons, the 1" 70 gallons, etc.

In the velocity meters the limit of head is exceedingly high. In the Hesse meter this limit is dependent almost solely upon the action of the rubber diaphragm. The difference of heads in chambers B and C, measuring about twice the effective pressure upon the diaphragm, will depend upon the square of the ratio of areas of the valve opening *d* and jet openings *a a*. In the meter tested the diaphragm is subjected to but $\frac{1}{20}$ of the total pressure lost in the meter, and this may be diminished at will by simple enlargement of the valve opening. By closing the opening *h* and fastening down the valve, the diaphragm was subjected to 25 feet of pressure without damage. The diaphragm then would not give way under a total loss of head in the meter of $25 \times 20 = 500$ feet. The further question which must be considered, is: Will the bellows operate under the rapid motion of the worm wheel due to high loss of head? A greater head than 60 feet was not available for trial, but in this case the time occupied in lifting cap K was only one-half the interval of high pressure. If the velocity of registering should be too great under very high heads, the difficulty is simply remedied by increasing the width of the arm, or the number of teeth, in the worm wheel. It is not thought that this would be necessary as the rate of supply of water to the bellows chamber is nearly proportional to the velocity of the measuring wheel.

8th. The compactness of the velocity meter is great as compared with that of the oscillating piston meter. This will appear from a comparison of the weights of meters of about the same delivery.

9th. The prices are given, as near as possible, in the following table: The price, as well as weight, increases much more rapidly with increase of delivery under the same head, in the piston meters, than of the velocity meters. In either form, the price increases at a smaller rate than the delivery. For example, a Kennedy 1 inch meter, delivering four times as much as the $\frac{5}{8}$ inch, costs less than 2½ times as much; the English Siemens 1½ inch, delivering five times as

TABLE OF DELIVERIES, GREATEST ADVISABLE RATES OF DELIVERY, WEIGHTS AND PRICES OF METERS.

Name of Meter.	Size of in and out lets. Inches.	Delivery unit 9 gals. per min. under eff. head of 20 feet.	Greatest Advisable		Weight in lbs. avoirdupois.	Price $
			Rate of delivery in gals. per min.	Effective head in feet.		
Worthington.....	⅝	1.0	7.5	16	59	17.00
	¾	?	15.0	——	103	27.00
	1	?	30.0	——	175	33.00
*Kennedy.....	⅝	1.3	19.9	60	104	19.36
	¾	1.8	30.0	——	162	27.83
	⅞	2.8	50.0	——	206	33.82
	1	5.4	70.0	——	322	46.00
	1½	11.0	150.0	——	564	75.00
English Siemens...	⅜	.2	* *	* *	?	12.10
	½	.5	——	——	?	14.76
	¾	.8	——	——	?	18.15
	1	2.0	——	——	?	21.30
	1¼	2.9	——	——	?	26.86
	1½	4.1	——	——	?	30.75
German Siemens..	1	2.5	——	——	33	26.00
Hesse	½	1.0	——	——	21	* * *

* The deliveries and greatest advisable effective heads in the Kennedy and English Siemens meters, were calculated from data furnished by the manufacturers' circulars. The Kennedy ¼ inch meter is omitted as it is not recommended by the manufacturing company.

* * The greatest advisable effective head is many times greater in the velocity than in the piston meters.

* * * A careful estimate of the cost of manufacture of the Hesse meter, indicates a price considerably less than that of any other meter named.

much as the ¾ inch, costs less than twice as much. Any comparison therefore of the price of meters of different delivery should be made with caution. The fallacy is apparent in the claim made by the Kennedy Co. to the effect that their 1 inch meter, delivering 2.02 times as much as the Siemens 1 inch, has over double the proportionate money value, and as it costs about 1.63 times as much as the Siemens, is therefore $\frac{2.02-1.63}{1.63}=24$ % cheaper. Reference to the table will show that the Kennedy ½ inch, delivering less than the Siemens 1 inch, costs considerably more.

The prices may be compared as follows:

(*a.*) Upon the basis of equal delivery, the list shows the Worthington to be cheaper for small sizes than the Kennedy or Siemens. As the deliveries increase, the Siemens become cheaper than the Worthington or Kennedy. The price of the Hesse has not been definitely ascertained.

(*b.*) Upon the basis of greatest advisable rate of delivery, the velocity meters are by far the cheapest, and the Worthington the most expensive. This is an important consideration only where there is on hand an abundant surplus of head for the house service. If, for example, the head is such as to make the capacity of the service pipe 10 or 12 gallons per minute, it becomes advisable to employ a ¾ inch Worthington, whereas a Siemens of far less delivery, or a ½ inch Hesse meter will amply serve.

10th. The expense of repairs of the English Siemens meter is permanently guaranteed by the Manufacturing Co. for 5 % annually upon the original cost. The actual expense in this and the Kennedy, seems to be in the neighborhood of 3 or 4 % per annum upon the original cost. It is claimed that the average life of the rubber roller in the Kennedy is more than three years. If the Worthington is overtaxed, the wear of the piston, etc., will necessitate expensive repairs in order to maintain its sensitiveness.

In the Hesse meter the life of the rubber diaphragm remains to be ascertained. It is known that pure rubber will deteriorate quite rapidly when exposed to air and light; but it is claimed that in cool water, under the exclusion of light and

air, it will remain intact for an indefinite period. The rubber diaphragm is not taxed as is the roller of the Kennedy. There was scarcely a perceptible wear in the Hesse meter during the passage of 62,000 cubic feet of water. The velocity of the measuring wheel (190 revolutions per cubic foot) is far less than in the Siemens meters of equal capacity, and its weight is trifling. The spindle does not pass through a stuffing box. The shaft P, which does pass through a stuffing box, makes only $\frac{1}{14}$ revolution for each cubic foot registered.

Conclusion.—The following is an attempt to rank the meters according to their merits with respect to the more definite of the considerations enumerated. This is done with a certain reserve, as, in some cases, the information at hand is not sufficiently complete to admit of positive conclusions. Where two meters are placed in the same vertical column no comparison between them is attempted.

1. Accuracy.....K. H. $W_{(A)}$. S. $W_{(D)}$.
2. Sensitiveness ...K. $\{W_{(A)}, H.\}$ $\{S., W_{(D)}.\}$
3. Permanency....H. K. $\{S., W.\}$
4. Greatest advisable rate of delivery. $\{S., H.\}$ K. W.
5. Compactness..... $\{S., H.\}$ W. K.
6. Price—(*a*). Upon basis of equal delivery under the same head..... $\{W., S.\}$ K.
   Price—(*b*). Upon basis of greatest advisable rate of delivery..... $\{S., H.\}$ K. W.
7. Expense of repairs.....H. $\{S., K., W.\}$

The Worthington, though sufficiently accurate, and quite sensitive when new, has very small advisable rate of delivery, and unless judiciously used is subject to deterioration with respect to sensitiveness.

The Kennedy, while extremely accurate and sensitive, and an excellent meter in other respects, is the heaviest and most expensive.

The Siemens meters are very compact and admit of a high effective head without damage; but, while their accuracy is sufficient for considerable rates of delivery, they are inferior in point of sensitiveness.

The Hesse meter combines, in the main, the good features of the others, with an advantage in respect to permanency of sensitiveness, price and wear.

Construction of the Hesse Measuring Wheel.—The following is an abstract of the statement made by Prof. Hesse with regard to the considerations which led him to the present construction of the measuring wheel, and the introduction of the stationary ribs.

A is the area of opening, a.

r, the radius of the wheel.

v, the velocity of the wheel.

c, the velocity of the water in passing opening a.

P, the effective pressure (reduced to radius r) of the jet upon the wheel, including all pressures, positive or negative, directly due to the action of the jet.

R, the resistance (reduced to radius r) caused by the displacement of the mass of the water.

F, the solid frictional resistance (reduced to radius 1), offered by the spindle journals and the worm wheel.

M and N, constant coefficients of pressure and resistance.

For permanent (uniform) motion of the wheel—

$$P = R + \frac{F}{r} \qquad (1)$$

The actual quantity of water delivered, $Q = Ac$.

The quantity registered, $Q^1 = Bv$, wherein B is a constant determined by the gearing, etc.

The ordinate in the curve of registry, $\frac{Q^1}{Q} = \frac{Bv}{Ac}$, is dependent upon P, R and $\frac{F}{r}$

On account of the variability in the workmanship and degree of wear, etc., upon the spindle journals and the worm wheel, the magnitude of F is subject to an unavoidable fluctuation of say 50%. Therefore, by diminishing the influence of F upon $\frac{v}{c}$ the permanency of the curve of registry is increased. It is evident also that, by diminishing the value of $\frac{F}{r}$, the Q necessary to move the wheel is lessened, *i. e.*, the meter is made more sensitive.

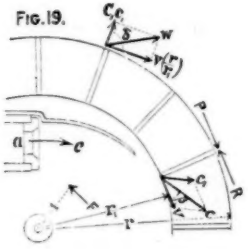
In order to show that velocity meters of this and similar forms are practicable, it is only necessary to point out that $\frac{v}{c}$ is approximately constant. If this ratio were strictly constant, such a value of B could be reached by adjustment as as to make $\frac{Bv}{Ac}=1$, and the meter would be perfectly accurate.

If the losses of head are assumed to be proportional to the squares of velocities, actual and relative, then

$$P\left(\frac{r}{r_1}\right)v=\frac{Q\gamma}{2g}(c^2-Cc_1^2-w^2),$$

wherein γ is the weight of unit volume of water, C a constant, c_1 the relative velocity of the water to the bucket, w the actual velocity of discharge. See Fig. 19. $Q=Ac$.

Fig. 19.



$$c_1^2=c^2+v^2-2vc\cos.\beta=c^2\varphi_1\left(\frac{v}{c}\right),$$

$$w_2=C_1^2c_1^2+\left(\frac{r}{r_1}\right)^2v^2-2(\cos.\delta)\left(\frac{r}{r}\right)C_1vc_1$$

Hence by transformation

$$P=\frac{A\gamma}{2g}\left(\frac{r_1}{r}\right)\left\{c^2\left(\frac{c}{v}\right)-c^2\varphi_2\left(\frac{v}{c}\right)-c^2\varphi_3\left(\frac{v}{c}\right)-c^2\varphi_4\left(\frac{v}{c}\right)\right\}$$

or

$$P=Mc^2\varphi\left(\frac{v}{c}\right) \qquad (2)$$

Wherein the function of the ratio of velocities, $\varphi\left(\frac{v}{c}\right)$, increases with decrease of v—*i. e.* the pressure upon the wheel increases when c remains constant and the velocity of the bucket, v, is forcibly diminished,

$$R=Nv^2$$

For $F=o$, by introducing values of P and R into equation (1).

$$Mc^2\varphi\left(\frac{v}{c}\right)=Nv^2,$$

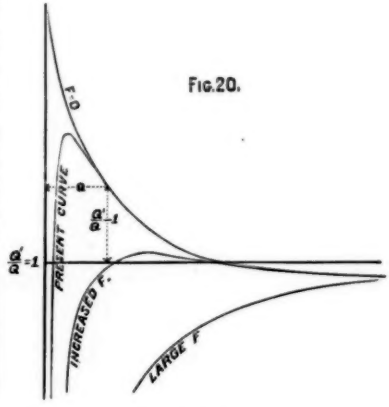
$$\frac{M}{N}\varphi\left(\frac{v}{c}\right)=\left(\frac{v}{c}\right)^2.$$

If then P were strictly proportional to c^2 and $\varphi\left(\frac{v}{c}\right)$, $\frac{v}{c}$ would be a constant for $F=o$.

However, the adopted law of loss of heads is a good approximation for considerable velocities only, therefore the result obtained indicates simply that, if the influence of F could be overcome, $\frac{v}{c}$ would not vary to any great extent, excepting for small rates of delivery.

The actual curve of registry, for $F=o$, is doubtless similar to that shown in Fig. 20.

Fig. 20.



For any value of F (see equation 1)—

$$P=Nv^2+\frac{F}{r},$$

$$v^2=\frac{P}{N}\left(1-\frac{F}{rP}\right)$$

The ordinate in the curve of registry—

$$\frac{Bv}{Ac}=\frac{B}{Ac}\sqrt{\frac{P}{N}\left(1-\frac{F}{rP}\right)}$$

This approaches the condition $F=o$, and the influence of a 50 % fluctuation of

F is the less, as the value of $\frac{F}{rP}$ is diminished—*i. e.* as F is diminished, or as *r* and P are increased.

It appears from the above that the meter will gain in sensitiveness and permanency:

(I.) by diminution of the solid frictional resistance (F);

(II.) by increase of the radius (*r*) of the measuring wheel;

(III.) by increase of the pressure (P) of the jet upon the wheel.

This increase of P may be effected:

(1) by reducing the area of the openings *a a*;*

(2) by increasing the resistance (R) of the water, and thus reducing the velocity (*v*) of the wheel. This increase of R is accomplished:

(*a*) by increasing the area of bucket, *i. e.*, the effective displacing area;

(*b*) by introducing stationary ribs, and thus checking in part the rotation of the body of water in the measuring chamber.

In one wheel tested, a high degree of sensitiveness was reached, by curving that portion of the bucket encountered by the jet, and arranging for outer feed, thus greatly increasing the pressure. However, such refinement was found unnecessary, and the small addition to the expense was not deemed advisable.

Due regard to the considerations enumerated, has led to sufficient sensitiveness and a high degree of permanency.

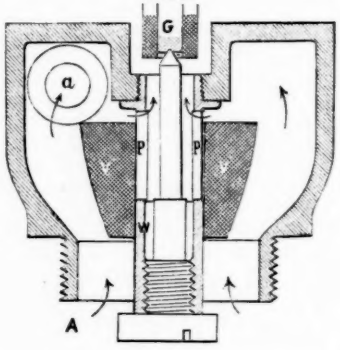
Improvement of the Curve of Registry.—There remains to be considered the question of a further improvement of the curve of registry. An immediate improvement of that portion of the curve corresponding to values of Q between 1 and 4 gallons per minute, may be effected by a small increase of F (see Fig. 20); but it must be borne in mind that such increase of F is necessarily accompanied by a considerable loss in sensitiveness.

Prof. Hesse devised the attachment shown in Fig. 21, with which the curve of registry was perfected without sacrifice of sensitiveness.

* This is a convenient method of improving the curve of registry, but is limited in its application on account of the corresponding reduction of the delivery of the meter under a given head.

The light hard-rubber valve V slips freely upon the outer surface of the tube W. If Q is considerable, say 6 gallons or more per minute, the valve V is lifted to its highest position and no water can escape through the openings *p p*. If Q, hence the effective head, is less, the valve

FIG. 21.



will occupy a lower position of equilibrium, and a small portion of the water will escape through the openings *pp* without assisting in the rotation of the wheel. Thus $\frac{Q^1}{Q}$ may be reduced more and more as Q becomes smaller. This reduction is experimently regulated by the width of the openings *p p*, and by the curvature of the surface of valve V.

This is important in connection with a test meter only. The present curve of registry is all that may be desired in a house meter, and certainly no device should be attached to the meter which would detract from the permanency or add to the liability to obstruction.

THE only place in America where graphite is now successfully mined is at Ticonderoga, N. Y. The output of the Ticonderoga mine in 1882 was 400,000 lbs., which will be increased to 500,000 lbs. this year. The mine is owned by the Joseph Dixon Crucible Company, of New Jersey, which is working a vein of graphitic schist, 15 feet, and carrying only from 8 to 15 per cent. of graphite. This is crushed and concentrated by a wet process, in which the "tailings" are the useful product. The Marquette *Mining Journal* believes that the graphite veins of the upper peninsula of Michigan, particularly those of Baraga County, are as pure and free from grit as either the New York, Canadian or Ceylon deposits.

WATER MOTORS *

By Professor W. CAWTHORNE UNWIN, M Inst. C. E.

From "The Engineer."

The lecturer remarked that water motors were not in this country so important as heat motors, but yet a larger amount of water power was utilized than was commonly supposed. Either a rise in the price of coal or greater ease in the electrical transmission of mechanical energy would make water motors more important.

At Windisch 1,000 horse-power were utilized, and at Bellegarde 3,700 horse-power. But it was in America that the largest installations were found. For instance, at Holyoke, a weir 30 ft. high and 1,000 ft. long had been built across the river, and the water, taken off above the dam in a canal 140 ft. wide and 22 ft. deep, supplied power to the mills. Two other canals, on lower levels, had also been constructed. The whole water power available was 20,000 horse-power in ordinary dry seasons, and the power was leased to the mill-owners at the rate of £1 per effective horse-power per annum.

When water was descending from a higher to a lower level, in a pipe, for instance, it would in general have acquired, at any point, velocity and pressure. Then if H was the total fall,

$$H = h + \frac{p}{G} + \frac{V^2}{2g}$$

where the terms on the right represent three forms the energy took, viz., unexpended fall, pressure head, and velocity head. Corresponding to these were three classes of water motors.

I. Cell or bucket wheels utilized the energy of an unexpended part of the fall. They were simple, had a fairly high efficiency, but were applicable only in a limited range of fall, and were cumbrous. They had one good point, that the efficiency varied little with a varying water supply.

II. There were water-pressure engines, which utilized water pressure, just as a steam engine utilized steam pressure. Water-pressure engines were used in mining districts, and hydraulic cranes and hoists were machines of the same kind. Still it was not generally best to utilize water power in this way. The reasons that a cylinder and piston acted so well with steam, and less well with water, were these: (1) The frictional losses in fluids were proportional to their weight for equal velocities of flow. If water were 500 times heavier than steam, then the friction at given velocities would be 500 times greater. Hence the piston speeds, which might be 400 ft. or 500 ft. per minute in a steam engine, were rarely greater than 60 ft. in a water-pressure engine. In the pipes the steam might flow at 100 ft. per second, but water only at 6 ft. to 10 ft. Hence the water-pressure engine was much more cumbrous than a steam engine. (2) From the incompressibility of water, the same volume was used in a pressure engine, whatever the amount of work to be done. The system of hydraulic-pressure-mains, introduced by Sir W. Armstrong, had proved entirely successful for intermittent work, such as lifting, but not so successful for ordinary power purposes. Probably the reason was that the consumption of water in pressure engines was extravagant. The only engine in which the consumption of water varied with the work to be done was in that invented by Mr. Hastie, and which, in an improved form, was being introduced in London by Mr. Ellington. In this, by automatic gear, the stroke of the engine was lengthened till the resistance was just overcome. (3) There were other difficulties which arose out of the weight and incompressibility of the water. The whole column of water between the engine and the supply-reservoir virtually formed part of the piston, so that a pressure engine had a very heavy piston, and this in general tended to render the effective effort variable. In certain cases the action of the friction and inertia of the water were favorable to particular

* Abstract of a paper read before the Institution of Civil Engineers.

operations. Mr. Tweddell's hydraulic riveter furnished an example of a machine in which the inertia of the parts was virtually that of 300 tons acting at the riveter-ram. To control such a mass, powerful brake action was necessary, and this was supplied by the automatic action of the friction of the water in the supply pipe. The friction, while preventing the velocity becoming excessive in the early part of the stroke, when there was little resistance, diminished when the velocity was checked in closing the rivet, and allowed the development of a high effective pressure at the end of the stroke.

III. There were motors in which the head was allowed to take the form of energy of motion, and in which the water acted in virtue of its inertia. It was first necessary to consider in what way this energy might be wasted. There was a waste of energy if the water broke up into eddies or irregular motions. Energy might be rejected from the machine into the tail race, and lastly, energy was lost in friction against the surfaces of the machine. In a good motor the loss due to breaking up could be almost completely avoided, if the passages changed gradually in section, if the surfaces had continuous curvature, and if the inclination of the receiving edges of the vanes was in the direction of relative motion. The loss due to rejection of energy could also be made very small, but by reducing this beyond a certain point, the loss from skin friction was increased.

The nature of a turbine would be best understood by considering first some simpler machines. In an ordinary undershot wheel about 25 per cent. of energy was rejected into the tail race and about 25 per cent. was lost in shock, besides the losses due to shaft friction and leakage. Suppose that instead of striking normally a flat float the water struck a hollow cup. Then both the losses in shock and in energy rejected were greatly reduced. An interesting motor of this kind had been introduced in California. Water power was there obtained from canals or ditches built to supply the mines, at elevations of from 1,000 ft. to 3,000 ft. above the valley. The fall was too great for an ordinary turbine, and a kind of undershot wheel with cup-shaped floats was used. Thus, at the Idaho mines, seven of these wheels were used, working to 320 horse-power. The water was brought in a 22in. wrought iron main, the head being 542 ft. The water was delivered on to the wheels from nozzles $1\frac{5}{16}$in. to $1\frac{15}{16}$in. in diameter. These wheels were said to give 80 per cent. efficiency, and in the special circumstances, where the jets were of small diameter under very high pressure, a high efficiency was probably obtainable. Such a wheel was the simplest form of an impulse turbine.

Next, consider a machine well known at one time as the Scotch turbine. The water, entering the center of the wheel, was discharged from tangential jets, and drove the wheel by reaction. The water issuing from the jets had a backward velocity, and energy was therefore rejected. It was the study of a wheel of this kind which led Fourneyron to the invention of the turbine. Fourneyron saw that the only way of reducing the backward velocity of discharge, and to prevent the waste of energy, was to give the water an initial forward velocity. The Fourneyron turbine was a reaction wheel in which initial forward velocity was given by fixed curved guide-blades. In the Fourneyron turbine, the water descending into the center of the wheel issued radially outwards. Its greatest defect was the form of the regulating-sluice, which diminished seriously the efficiency for diminished water supply. It was followed by the Jonval turbine, in which the water flowed parallel to the axis, and by the inward-flow turbine first perfected by Professor James Thomson. In the ample space outside an inward-flow turbine, better regulating apparatus could be arranged than with any other form.

In all turbines as first constructed, the water issued from the guide blades with a velocity less than that due to the head, and, therefore, there was a pressure in the clearance space between the guide blades and the wheel, and such turbines were called pressure turbines.

M. Girard was the first to receive the advantage of departing from Fourneyron's practice, and to allow the water to enter the wheel with the whole energy of motion due to the head. Such turbines were called impulse turbines. In

pressure turbines the water must enter the whole circumference of the wheel simultaneously, and fill the wheel passages, or the pressure in the clearance space could not be maintained. Further, there must be rate of flow through the wheel to maintain the distribution of pressure and velocity for which the turbine was designed. In impulse turbines each particle of water acted for and by itself; the wheel passages were not filled, and the water might be shut off from any part of the wheel circumference without affecting the action of the water. Regulation was therefore easier in impulse than in pressure turbines.

The consideration of the action of water in a turbine was facilitated by replacing the turbine wheel by a turbine rod, that was by supposing the turbine to have straight instead of circular motion. From such a rod, the transition to the case of a turbine wheel by simple projection was easy. The water entering vertically, was deflected by fixed guide blades, till it had a horizontal velocity, w_i ; it then entered the wheel, the vanes of which were so placed as to receive it without shock, and was deviated back to a vertical direction, having given up all its horizontal energy of motion. Hence, applying Newton's second law $\frac{w_i}{g}$ was the horizontal pressure driving the wheel due to each pound per second of water. But V being the velocity of the wheel, the work done on the wheel, $\frac{w_i\,V}{g}$ foot-pounds per second. Now the work might also be written ηH, where H was the effective fall, and η the efficiency. Hence

$$\frac{w_i\,V}{g} = \eta H$$

was the fundamental equation in designing a turbine.

There was one point in the action of a turbine which was unfavorable. The efficiency varied with the speed. There was a speed of maximum efficiency. But with pressure turbines the speed of maximum efficiency diminished with the closing of the sluice. Now, in general, a turbine must be run at one speed. If it was run at the speed of greatest efficiency for a full sluice, then for a partially closed sluice the efficiency was reduced both by the action of the sluice and by the fact that the speed was not the best for that position of the sluice. In the mode of regulating turbines great differences of efficiency arose. The worst mode of regulation was by a throttle valve, which acted by destroying part of the head. Next to this perhaps the worst was the circular sluice, used with the Fourneyron turbine. Some modern turbines gave, in experiments which appeared to be reliable, much better results. The best mode of regulation for a pressure turbine was by means of movable guide-blades, invented by Professor James Thomson. In a Girard turbine the regulation was not so difficult, and results of an experiment carried out under the direction of Professor Zeuner on a 200 horse-power Girard turbine gave 79.5 per cent. efficiency with full sluice, and 80.1 per cent. with half sluice.

ON THE ANTISEPTIC TREATMENT OF TIMBER.

By SAMUEL BAGSTER BOULTON, Assoc. Inst. C. E.

From Papers of the Institution of Civil Engineers.

I.

In January, 1853, a paper upon Timber Preserving was contributed to this Institution by the author's partner, the late Mr. Henry Potter Burt, Assoc. Inst. C. E. Since that date, the use of Antiseptics for the treatment of timber has largely increased, and is year by year increasing. For engineering purposes, the process called creosoting, which consists in the injection of the coal-tar oils, has in this kingdom entirely, and in other countries to a very considerable extent, displaced the other well-known methods.

Concurrently with this development, a series of remarkable discoveries in chemical science has raised the manufactures connected with the residual prod-

ucts of gas-making to a position of great and growing importance.

It is proposed in the present paper, to give a short account of the history and development of the use of antiseptics for preventing the decay of timber. A reference to the processes employed in coal-tar distillation will be pertinent to the subject, in so far as it will indicate what are and have been the usual constituents of the tar oils used for injecting wood. The author proposes to add some results derived from his thirty-four years' experience in connection with this group of manufactures, together with the outcome of some research, and of a number of experiments specially undertaken with a view to the elucidation of questions referred to in the paper.

EARLY HISTORY OF TIMBER PRESERVING.

Timber was naturally the first material employed by man for the purposes of constructive engineering. If it be true that the first models of Grecian architecture were copied from, and retained some of the distinctive features of, buildings in wood, then may still be seen recorded, upon the columns of the five great orders of architecture, proofs that the Greeks or their precursors took special expedients to preserve timber from decay. The wooden pillar was placed upon a block of stone to preserve it from the humidity of the soil, and it was covered at the top by a slab or tile to throw off the rain. These contrivances are supposed to have been copied in the base and capital of the column, when wood came to be replaced by stone. Scamozzi imagines also, that the mouldings represent metal hoops, placed around the wooden pillars to prevent them from splitting.

Allusions to various substances employed for preserving timber and other vegetable fibers from decay, are frequent in the writings of the ancients. Tar and pitch were used for painting or smearing wood from periods of the most remote antiquity. Greek and Róman authors narrate, that the astringent portions of the oil expressed from olives (Amurca 16), also oils derived from the Cedar, the Larch, the Juniper and the Nard-Bush (Valeriana) were used for the preservation of articles of value from decay, or from the attacks of insects. The magnificent statue of Zeus by Phidias was erected in a grove at Olympus where the atmosphere was damp; the wooden platform upon which it stood was therefore imbued with oil. The famous statue of Diana at Ephesus was of wood. If its origin was believed to be miraculous, no standing miracle was relied on for its preservation. Pliny asserts upon the authority of an eye-witness, Mucianus, that it was kept saturated with oil of Nard by means of a number of small orifices bored in the woodwork. The same author remarks that wood well rubbed with oil of Cedar, is proof aginst wood-worm and decay. The art of extracting and preparing oils, resins, tar and pitch from various trees and plants, and from mineral deposits, is mentioned by Herodotus, and at great length by Pliny. This last author describes in detail, the manufacture of no less than forty-eight different kinds of oils. Of the employment of the oxides or salts of metals by the ancients, for wood preserving, there is no direct evidence.

EGYPTIAN MUMMIES.

Of all the methods employed by mankind for the artificial preservation of organized substances, there are perhaps none which have equaled in success the processes of the ancient Egyptians. The durable results of these processes are amazing, and although the topic is a hackneyed one, it is nevertheless inseparably connected with the subject of this paper. The descriptions by co-temporary writers of the Egyptian art of embalming the dead are somewhat conflicting; moreover, they do not adequately explain the appearances presented by many of the mummies themselves. The bodies are said to have been imbued, either with resinous or odoriferous gums, or more frequently with bitumen or with oil of cedar, or commonly with natrum, and often with several of these substances in succession. So far, these statements are confirmed by modern investigation. By reading Herodotus and Diodorus Siculus, however, it would perhaps seem that the body was first steeped in the natrum for seventy days, and then subjected to the oily or bituminous preparation. In other places it might be gathered that the oily preparation came first, and the steeping

in natrum afterwards. Without further explanation, neither of these processes would appear to be practicable. At ordinary temperatures, the steeping in the one preparation would interfere with the absorption of the other. Natrum is supposed to have been a natural substance, obtained from some briny lakes, still existing in the neighborhood of Cairo, and consisting principally of a mixture of sodium-sesqui-carbonate, sodium-chloride and sodium-sulphate. Rouyer, who accompanied the army of Napoleon to Egypt in 1798, expressed his conviction that the mummies had been placed in ovens in order to eliminate moisture, and to facilitate the penetration of the bitumen. But no ancient author mentions any such process, nor is there any record of it amongst the numerous and detailed pictorial representations which have been discovered in tombs and temples.

Pettigrew, in his valuable work on this subject, whilst giving the results of his examination of various mummies, and of analyses of embalming materials, expresses his opinion that the bodies must have been subjected to a very considerable degree of heat, as even the inmost structure of the bones is penetrated by the antiseptics. By some it has been supposed that this was effected by steeping the body in a cauldron of heated bitumen. Pettigrew's most striking experiment was made with the heart of a mummy, from which he succeeded in withdrawing by maceration the preservative substances, when, after 3,000 years of perfect preservation, the heart began at once to putrefy. This is a striking proof, both of the efficacy of the substances employed, and also of the fact, that the immunity from decay was not due to a chemical transformation produced once for all, but that it depended upon the abiding presence of the antiseptic. In recent anatomical practice, carbolic acid has been used for injecting bodies for purposes of dissection. When this is done, however, it is found necessary to renew the process after the lapse of a few weeks, a contrast to the antiseptics employed by the Egyptians. Pettigrew's description showed that the worst preserved of the mummies are those prepared with natrum alone, the most perfect being those in which solid resins or bitumens remain incorporated. Natrum is frequently found accompanying the bitumen in some of the most successfully preserved specimens. It is probable that some astringent or other substances were also used, the secret of which has hitherto eluded modern investigation.

The author has caused some experiments to be made with pieces of timber, in order to test a theory which suggested itself to his mind. The wood was first thoroughly impregnated with a mixed solution of the three salts of sodium of which the natrum brine is composed. Afterwards the wood was steeped in tar oil, heated to 230° Fahrenheit. The heat of the tar oil volatilized the water of the soda solution, and the oil took the place of the water. The timber remained impregnated with the saline particles, and saturated with the tar oil. May not this have been the method used by the Egyptians to impregnate both with natrum and oils?

There is no doubt that the ancients had, by observation and experience, acquired considerable practical knowledge of antiseptic substances. They were also of opinion that those woods lasted the longest which were most odoriferous, or, in other words, those which contained the greatest quantity of resin. They knew that timber continually kept under water was less liable to decay than when exposed to the atmosphere. They observed the ravages of the *Teredo navalis* upon timber placed in the sea. But it is useless to seek amongst the writings of the elder Classics for any reasonable theory in explanation of these phenomena.

Growth of theories upon the causes of Putrefaction.—It is not until the eighteenth century of the present era that anything beyond the merest trace can be detected of serious analytical research into the causes of decomposition. After the fanciful dreams of the alchemists had been dissipated, the more solid portion of their labors, facts arrived at in the course of their experiments, remained for the uses of science. Investigations were undertaken respecting the phenomena of fermentation and of putrefaction, animal and vegetable. It was at one time declared that putrefaction was due to the escape of an element called phlogiston, an imaginary substance which was believed in by such eminent chem-

ists as Scheele, the discoverer of chlorine, and Dr. Priestley, the discoverer of oxygen. Later on Dr. Macbride propounded a theory that carbonic acid gas had a special power of promoting cohesion, and that putrefaction was due to its being given off. None of these theories explained why putrefaction did not attack the tissues until after the vital movement had ceased. By the commencement of the present century, however, it began to be generally believed that the putrefaction, at least of vegetable matter, was a species of fermentation, although it was not admitted that ferments of any kind were the products of living organisms. Little by little the similarity of the natural processes connected with the fermentation of alimentary substances, the decay of vegetable tissues, and the putrefaction of the bodies of animals began to be recognized; and, to the great advantage of scientific progress, these three classes of phenomena have ever since been studied in close connection with each other.

In the meantime practice stole a march upon theory. About the year 1770 Sir John Pringle published a list of antiseptics, in which example he was followed by Dr. Macbride. Many of the substances proposed by these and other theorists, particularly the alkaline bodies, are absolutely injurious to timber. But towards the close of the last century and at the beginning of the present, experiment was greatly stimulated by the wants of the British navy. During the colossal struggles of Great Britain with hosts of adversaries, the very existence of the nation appeared to be staked upon her fleets. The great prevalence of dry-rot in the timbers of British men-of-war assumed the proportions of a national calamity. It was said that a single 70-gun ship required for its construction the oak of 40 acres of forest, and that the supply would fail. It was in 1812 that Lukin tried, in the Woolwich Dockyard, his disastrous experiment with the injection of resinous vapors. More practical suggestions were soon forthcoming, and the use of the salts of various metals began to be recommended. Sir Humphrey Davy suggested corrosive sublimate; Thomas Wade (in 1815), the salts of copper, iron, and zinc. The opinion gained ground that poisons of various kinds were correctives to the decay of timber.

From the year 1768 up to the present time, the records of the Patent Office contain lists of almost every conceivable antiseptic, suitable or unsuitable, for the preservation of wood.

Progress during the Railway Era.—But it is since the birth and growth of the railway system that the antiseptic treatment of timber may be said to have received its most important development. The stone blocks and other solid supports, at first used for the permanent way of railways, were found to be too rigid, and had to be replaced by a more elastic material. The wooden sleepers which were substituted decayed so rapidly that some artificial method for prolonging their duration began to be considered as an engineering necessity. By the year 1838, four several systems of antiseptic treatment were fairly before the public, and competing for the favor of engineers. These were: Corrosive sublimate, introduced by Mr. J. H. Kyan; sulphate of copper, by Mr. J. J. Lloyd Margary; chloride of zinc, by Sir William Burnett; heavy oil of tar (afterwards called creosote), by Mr. John Bethell.

Corrosive Sublimate, or bi-chloride of mercury, was successfully used by Homberg, a French savant, in 1705, for preserving wood from insects. It was recommended by De Boissieu in 1767. In 1730 the Dutch Government tried it upon wood immersed in sea water as a remedy against the *Teredo navalis*, but for this purpose it failed. In the "Encyclopædia Britannica," in 1824, it is recorded that Sir Humphrey Davy recommends its use for timber. Kyan's first patent, for the employment of corrosive sublimate for wood-preserving was taken out in 1832. His first success was gained by the preservation of the woodwork of the Duke of Devonshire's conservatories. Kyanizing was for a long time by far the most popular of the timber-preserving processes in this country, and the name is to this day frequently applied erroneously to other systems. Used in sea-water, however, by the British Admiralty, this process turned out a failure, as it had done under similar circumstances with the Dutch government a century earlier. Kyanizing has met with a considerable amount of success in compara-

tively dry situations; but in water, and particularly in sea-water, it appears to have invariably failed, as have all the salts of metals. Corrosive sublimate is somewhat volatile at ordinary temperatures; it also has the drawback of producing injurious effects upon the workmen employed in handling it.

Sulphate of copper.—The use of this and of other salts of copper was recommended by De Boissieu and by Bordenave in 1767, and by Thomas Wade in 1815. In 1837 Mr. Margary took out a patent for the use of sulphate and ascetate of copper. Sulphate of copper has perhaps been the most successful of all the metallic salts as an antiseptic for timber. Applied in various ways it was popular in France long after it had been given up in this country. It is still in use in France, to a limited extent, for sleepers and telegraph poles.

Chloride of zinc.—This was recommended by Thomas Wade in 1815, and by Dr. Boucherie in 1837; and a patent for its application was taken out in this country by Sir William Burnett in 1838. The process of Burnettizing was at one time much patronized by the British Admiralty. For railway sleepers it was extensively adopted in France by the author's firm, principally on the railways from Orleans to Bordeaux, and from Caen to Cherbourg. It is no longer used in France, but it is still employed in Holland and in Germany. Chloride of zinc is a powerful antiseptic, but its weak point for wood-preserving consists in its extreme solubility in water.

Heavy oils of Tar, commonly called Creosote.—As early as 1756 attempts were made, both in England and America, as described by Knowles, to inject or impregnate timber with vegetable tars or with extracts therefrom. The first mention of the products of the distillation of gas-tar, to be used separately for impregnating timber, appears to be by Franz Moll. This inventor took out a patent in 1836 for injecting wood in closed iron vessels with the oils of coal-tar first in a state of vapor, and next with the heated oils in the ordinary liquid state. He recommended the adoption both of the oils lighter than water, and of the oils heavier than water, calling the former "Eupion," and the latter "Kreosot." He relied upon the Kreosot for its antiseptic qualities, but proposed to use the light oils separately, at the commencement of the operation, for the purpose of facilitating the absorption of the heavy oil. This plan has never been acted upon, as it would be obviously wasteful and unpractical to inject the lighter oils, or crude naphthas, which would immediately evaporate.

The practical introduction of the process is due to Mr. John Bethell. His now celebrated patent, which is dated July, 1838, does not mention the words "Creosote" or "Creosoting." It contains a list of no less than eighteen various substances, mixtures or solutions, oleaginous, bituminous, and of metallic salts. Amongst them is mentioned a mixture consisting of coal-tar thinned with from one-third to one-half of its quantity of dead oil distilled from coal-tar. This is the origin of the so-called Creosoting process. Creosote, correctly so called, is the product of the destructive distillation of wood, and coal-tar does not contain any of the true Creosote, which has never been used for timber-preserving. But a substance, since called carbolic acid, or phenol, had been discovered in coal-tar; it was thought by some to be identical with the Creosote of wood, hence the process came to be miscalled, after a time the creosoting process. It is in this popular sense only that the word Creosote is to be understood in the remainder of this paper. The two substances, Creosote and Carbolic acid, are described and contrasted, and their varying properties delineated in Dr. Tidy's "Handbook of Chemistry."

Competition of the Processes—Theory of Eremacausis.—In addition to the four processes already mentioned, a patent for a fifth was taken out by Mr. Charles Payne in 1846. His plan consisted in the injection into the timber, first of a solution of a sulphuret of barium or calcium, and next of a solution of sulphate of iron, the object being to form an insoluble sulphuret in the pores of the wood. This process was tried to some extent both in England and in France, but it was a complete failure, and is mentioned only by way of reference.

From 1838 to 1853, at which last date the paper of Mr. H. P. Burt was read at this institution, the four processes, Kyanizing, Margaryizing, Burnettizing and

Creosoting had been in active competition. The prevailing theory at that time as to the causes of the decay of timber was shaped by the opinions of the great chemist Liebig. Liebig taught that the processes of fermentation in certain fluids and of the putrefaction or decay of organized bodies, animal and vegetable, were caused by a species of slow combustion, to which he applied the term eremacausis. He held that this decomposition could be produced by contact with portions of other bodies already undergoing eremacausis. That it required for its ordinary development the presence of moisture and of atmospheric air; that its action was provoked by oxygen, and that its method of action was by a communication of motion from the atoms of the infecting ferment to the atoms of the body infected. He denied that fermentation, putrefaction and decomposition were caused by fungi, animalcules, parasites or infusoria, although these organisms might sometimes be present during the processes.

But he also stated that the phenomena of decomposition might be suspended by extreme heat or cold, that they were accelerated by the action of alkalies, and retarded by that of acids, and that they might be arrested by the use of certain antiseptics. If, however, the theory of eremacausis be accepted, and if its phenomena be due entirely to a communication of molecular motion, and not at all to the action of living germs, does any adequate explanation remain of the effects produced by antiseptics? With regard to timber, theorists were ready with an answer to this question, and they deduced their theories from further teachings of the great German chemist. Liebig, enlarging upon the views of previous investigators, had proclaimed the identity in composition of the animal and vegetable albumens. The blood of animals and the sap of plants are, during life, the circulating media of the vital growth; after death they are the portions of the respective bodies which putrefy most rapidly; both are largely composed of albumen. The sap freshly drawn from a tree will commence to putrefy within twenty-four hours. It was proclaimed (although probably not by Liebig), that the coagulation of the albumen was the true specific against the decay of wood. Corrosive sublimate, sulphate of copper, chloride of zinc, and the tar oils were all powerful agents for that purpose. It was claimed for all four of these processes that they coagulated the albumen contained in the wood, and that they formed insoluble compounds therein, thus arresting decay.

Prolonged experience has, however, proved that the salts of metals are not so permanent in their effects as the tar oils. The discussion which took place at this institution in January, 1853, upon the occasion of the reading of Mr. Burt's paper, was an interesting one, and was joined in by most of the leading engineers of the country. Whilst the other processes were admitted, in many instances, to have done good service, the Creosoting process was generally held, after fifteen years' experience, to have proved the most stable and reliable. In many subsequent discussions, the prolonged duration of creosoted timber had been a matter of constant and reiterated testimony. Gradually the Creosoting process took the place of the others by a species of "survival of the fittest," until in England it entirely extinguished its rivals. The author's last experience of Kyanizing in England was carried out in 1863.

In France, the Creosoting process was later in establishing itself, partly owing to the difficulty which at one time existed in procuring Creosote in that country, partly, also, to the popularity of the sulphate of copper process, enhanced, as it was by the ingenuity of the method employed for its injection by Dr. Boucherie. But it was discovered even in France, and notwithstanding the theories of insoluble compounds being formed in the timber, that the salts of metals were gradually washed out of the wood in moist situations. In 1861, the French chemist Payen reported that sulphate of copper could be almost entirely removed from wood by repeated washings with water, and in 1867 he reported that the whole could be so removed. This has been confirmed by the testimony of Maxime Paulet.

The experiments of Mr. Forestier, undertaken for the French Government, and the prolonged and exhaustive experiments of the Dutch Government, are conclusive as regards the efficiency of

creosoting against the ravages of the *Teredo navalis*, in cases where the timber has been efficiently prepared, and with a suitable kind of creosote. These experiments are referred to in the Minutes of Proceedings of this Institution, vol. xxvii. The experiments undertaken by Mr. Crepin on behalf of the Belgian Government, and the independent testimony of many of the leading engineers of this country, have also from time to time been brought to the notice of this Institution, in confirmation of the success of the Creosoting process against the ravages of marine insects. On the other hand, there are distinct and well authenticated instances of failure. An inquiry into the causes of such failures is one of the main objects of this paper.

Origin and properties of the Tar Oils.—As the tar oils gained in usefulness, their varying qualities became subjects of increasing interest. A brief digression may here be useful, in order to show the process of manufacture by which these tar oils are procured. It will be seen that from coal, as it is carbonized at the gasworks, four well known products are obtained, viz., illuminating gas, ammoniacal liquor, coal-tar, and coke. Gas liquor, or ammoniacal liquor forms the basis of a separate industry; the ammoniacal products are of no utility for timber preserving. The antiseptic substances are all obtained from the distillation of coal tar, a black, viscous substance of a consistency resembling treacle. The tar is subjected to the heat of a furnace placed beneath the still, the operation being aided sometimes by the injection of steam, sometimes by the application of an exhausting air pump. The products of distillation come over very nearly in the order of their respective volatilities, those of lightest specific gravity being followed in succession by heavier and yet heavier ones as the heat increases. The temperature during the distillation ranges from 180° to 758° Fahrenheit. This preliminary process, although now carried out with more skill and economy than formerly, has not varied much during the last fifty years in its main object, which is to break up the tar into three groups of products, viz., oils lighter than water (crude naphthas); oils heavier than water, pitch, the residuum of distillation, which last product is run out from the bottom of the still, and solidifies, upon cooling, into a hard, black substance. It is in connection with the component parts of the two groups of oils, and their separate and subsequent treatment, that some of the best known and most brilliant discoveries of modern industrial chemistry have been developed. The oils lighter than water, however, have no part in the preservation of timber. It is not uncommon to hear inquiries as to whether the discovery of the aniline dyes has not, somehow or other, interfered with the quality of the Creosoting liquor. There exists a singular and unfounded prejudice on this subject. The materials for the aniline dyes are not, and never have been, taken from the Creosoting liquor or heavy oils; they are taken exclusively from the oils lighter than water, which last have never been employed for the Creosoting process, and are valueless for timber-preserving. The benzols, toluols, &c., from which the aniline dyes are produced, are extremely volatile, like alcohol.

The heavy oils of tar, or dead oils heavier than water, constitute the "Creosote" of the timber yards. They contain numerous substances, some of them liquid, some semi-solid, varying considerably in their properties, but most of them are now recognized as antiseptics. Formerly, the whole mass of these heavy oils was used for timber-preserving as they were collected from the still, but each portion can, if required, be separated as it comes over, according to its volatility, or the solid matters can be separated by filtering, for subsequent treatment.

It has been seen that Mr. Bethell's original patent recommended the use of the mother liquor, or coal tar, thinned with a portion of heavy coal-tar oil. So late as 1849, Bethell's licenses for the use of his patent described the process as "saturating timber with the oils obtained by the distillation of gas-tar, either alone or mixed with gas-tar." The author remembers how, in the early days of Creosoting, inspectors frequently refused to allow the thinner and lighter dead oils to be used without being thickened with tar. Tar, the mother liquor, necessarily included all the substances contained in the dead oils, plus the naphthas and the pitch. The reasons for not

adopting the tar in its entirety are simply that the crude naphthas are useless as antiseptics, and would immediately evaporate, whilst the pitch, from its too great solidity, would form an impediment to the injection. The dead oils, therefore, came into use alone, and there crept into some of the specifications the contradictory prescriptions that the wood was to be Creosoted according to Bethell's patent, but that the Creosote was to be free from adulteration with coal tar.

The dead oils made in London, and in all places where the tar is produced from the carbonization of the coal of the Newcastle district, are, as compared with other dead oils, the richest in semi-solid substances (naphthalene, anthracene, pyrene, &c.), and they require a higher temperature to volatilize. They are generally called "London oils." The dead oils of the Midland Districts are lighter, thinner, and more volatile, and contain usually a larger proportion of the ordinary tar acids. They are usually called "Country oils." The Scotch oils are, many of them, still lighter, thinner, and more volatile, sometimes lighter than water. Some Scotch oils, however, have been proved to be of excellent quality.

As regards the question of thick or thin oils, there is no doubt as to the opinion and practice of the earlier introducers of the Creosoting process. In January, 1853, Mr. Bethell stated that "the product of Newcastle coal contained a quantity of naphthalene, and that he was an advocate for its use." In November, 1864, he said that "the Creosoting process was not, as often described, a chemical process entirely"; that Creosote did coagulate albumen in the sap of the wood; "but that was not his only idea when he introduced the process: his object was to fill the pores of the wood with a bituminous asphaltic substance, which rendered it waterproof," &c.

The late Mr. H. P. Burt, whose labors in connection with the preservation of timber will be remembered by many of the elder members of the engineering profession, was in the habit, for many years, of using, by preference, the heavy London oils, mixed at times with a small percentage of the country oils, the latter as solvents or diluents of the more solid material. The author, whose connection with Mr. Burt commenced in 1850, remembers, among his first experiences of creosoting, the solid masses of naphthalene contained in the tanks before heating.

When the construction of railways commenced in India in 1850 and 1851, it was speedily discovered that the timber found in that country was subject to very rapid destruction by decay and by the attacks of insects. A serious difficulty was encountered by engineers in procuring suitable sleepers, and the experiment was tried of sending creosoted Baltic timber from this country. The first consignment of this material was sent out in December, 1851, for the East Indian Railway Company. The results were promising from the first, and the exportation of creosoted sleepers to India continually increased. The Minutes of Proceedings of this Institution contain numerous records of the rapid decay of unprepared timber in tropical climates, and also of the very great general success of creosoted timber exposed to the same influences, chequered, however, with a few instances of partial failure, which should be as instructive as the successes. It may be interesting to refer to the two papers by Mr. Bryce McMaster, upon Indian Permanent Way materials, one read in 1859, and the second in 1863, in which the success of creosoted timber in India is fully set forth. Mr. Juland Danvers, in his annual report to the Secretary of State for India for the year 1863, remarks that it is cheaper to send out creosoted Baltic sleepers than to use those of indigenous wood. The printed report of the East Indian Railway Company for the year 1867 again records the success of creosoted sleepers, after sixteen years' experience of their use.

It becomes a matter of interest to ascertain the kind of Creosote which was used for these earlier Indian sleepers. When the exportation first began there was a custom's duty upon the importation of Baltic timber into this country equal to about 20 per cent. on the value of the sleepers. The author's firm made early arrangements for creosoting in bond, and for this reason, and with trifling exceptions, all the sleepers sent abroad, although supplied by various contractors, were for many years creo-

soted at the works of the author's firm at Rotherhithe and at the Victoria docks. Their books contain accurate records of the origin of all the creosote used. As may be anticipated, by far the greater bulk was London oil, up to 1863 comparatively little country oil, and in some years none at all being used. In January, 1853, Mr. Burt, in describing to this Institution the process which he used, spoke, as a matter of course, of Creosote becoming a hard, compact mass at a temperature below 35° Fahrenheit. Ten years later, in February, 1863, speaking with reference to the Creosoting of some sleepers, the success of which in India had just been announced, he described Creosote as becoming solid at a temperature below 40° Fahrenheit, and added that, in consequence, he had introduced a heating apparatus inside the Creosoting cylinder.

With the exception of a small experimental shipment of larch and Scotch fir, all the sleepers sent to India have been of Baltic fir timber from the Polish and Russian ports. The shipments were of the ordinary kind of wood, such as was in use at first for sleepers in this country, and were mostly of triangular section. Amongst them, for the first three or four years, were considerable quantities of white-wood, a wood somewhat liable to split in hot countries. Subsequently, red-wood was stipulated for, and with good reason, in all Indian specifications. The quantity of Creosote injected into these sleepers was at first from 35 to 40 gallons to the load of 50 cubic feet, as compared with the 50 and 60 gallons of the present day. At present not only is a larger quantity of Creosote injected, but more care is also expended in the selection of the wood than was formerly the case. If, therefore, the earlier sleepers shipped to India behaved well, it might be assumed that the quality of the Creosote, at least, was suited to the climate. Such Creosote, however, as was then used would now be rejected under the requirements of many of the specifications at present in force for the preparation of timber for tropical countries. It is a question for grave consideration whether the change has been for the better.

It is a matter of notoriety, that for many years an increasing demand has arisen for the thinner and lighter Creosotes. "Country oil" became more popular, and began to be mentioned in specifications. Inspectors preferred these thinner oils; they were injected with less trouble, and the timber looked cleaner and less "muddy" after the process, especially in the winter, when the London oils are more solid. Contrary to the opinion of the introducers of Creosoting, the thin, light "Country oil" came to be considered by many as the supreme type of excellence.

This view was adopted by the late Dr. Letheby, who was further influenced by the growing recognition of the wonderful antiseptic powers of carbolic acid. Discovered in coal tar by Runge, a German chemist, in 1834, carbolic acid had gradually achieved the important position which it still holds as one of the most valuable of antiseptics for sanitary and surgical puposes. Carbolic acid in varying quantities was present in the tar oils; the other constituents of those oils were imperfectly understood; some of them, now well known, had not then been discovered. The success of the creosoting process was therefore by *a priori* reasoning attributed mainly, if not solely, by Dr. Letheby to the presence of the tar acids. In June, 1860, Dr. Letheby published his views on this subject in the "Journal of the Society of Arts." He considered carbolic acid to be the most effective constituent of the tar oils, and that the efficiency of the latter in preserving timber depended mainly upon the percentage of carbolic acid which they contained. He therefore concluded that the lighter portions of the dead oils were the best, viz., those portions distilling between 360° Fahrenheit and 490° Fahrenheit, as they contain the tar acids in greatest abundance. Naphthalene and para-naphthalene he desired to exclude as much as possible, as he held them to be of no value in the preparation of timber. He had found the proportion of carbolic acid in tar oils to range from 6 per cent. down to as low as 0.5 per cent. In a letter of his in the author's possession, dated 5th June, 1863, he alludes to two samples as containing "unusually large" proportions of tar acids; the quantities were respectively 6.4 per cent. and 10.1 per cent. In a lecture at Nottingham, in 1867, Dr. Letheby described

a specification which he had drawn up for an Indian railway. This specification, dated 1865, contains the following stipulations: The creosote is to have a specific gravity as near to 1,050 as possible, ranging from 1,045 to 1,055. It is not to deposit naphthalene or para-naphthalene at a temperature of 40° Fahrenheit. It is to contain 5 per cent. of crude carbolic and other coal-tar acids (by the caustic potash test). It is to yield 90 per cent. of liquid oil, when distilled from its boiling point to a temperature of 600° Fahrenheit.

From an examination of upwards of seventy timber-preserving specifications in the author's possession, ranging from 1849 to the present year, it is manifest that a new departure was thus inaugurated by Dr. Letheby. For the first time a boiling-point is fixed, a certain percentage of tar acids insisted upon, whilst the use of naphthalene and the heavier distillates is discouraged. This specification has long ceased to be used, but its stipulations have been copied, and in some cases carried to greater lengths, in more modern specifications, 10 per cent. of tar acids being occasionally required. Such specifications exclude the London oils if taken in their entirety as they come from the still. It is to be regretted that, at the period mentioned, there is no record of experiments having been made by any English chemists as to the actual effects produced upon timber by the various constituents of the tar oils taken separately. For want of such a test, it would appear that an important element in the question was for some years overlooked in this country.

So early as 1848 the French Académie des Sciences received a communication from De Gemini, detailing a series of experiments upon wood prepared with various antiseptics. This investigator endeavored to prove that timber cannot be permanently preserved by the use of antiseptics which are themselves soluble in water, and for that reason he preferred the use of heavy oils, or bituminous substances. The Academie rejected the conclusions of De Gemini, more especially as he denied that solutions of sulphate of copper formed insoluble compounds with woody fiber.

In 1862 Mr. Rottier presented a paper to the Academie Royale de Belgique giving the results of a number of experiments as to the effects upon timber of the various constituents of coal-tar oil. He arrived at the conclusion that although carbolic acid (L'Acide Phénique) was a very energetic antiseptic, yet that, owing to its volatility, the durable success of the Creosoting process was not due to its agency. He attributed that success to the heavier and less volatile portions which came over at the later periods of the distillation, and considered that the heavier they were the better.

Later on this investigation was taken up by Mr. Charles Coisne, who was then, and still is, an engineer in the service of the Belgian Government. In 1863 Mr. Coisne commenced a series of experiments, the object being to determine, in a practical manner, which portions of the tar oils best preserved the timber. The results were so instructive, that in 1866 he inaugurated a new series of experiments, still more carefully conducted, which lasted until 1870. He procured samples of Creosote from England, Scotland, Belgium and France. Four of these samples contained, respectively, 15 per cent., 15 per cent., 8 per cent., and 7 per cent. of tar acids by the usual test. The fifth was an oil of heavy specific gravity, specially prepared, and containing no tar acids. Yet this last sample produced better results than any of the others. Each sample was divided into portions. Wood shavings were saturated with these oils in the following different ways:

1st. With the Creosotes as received.

2d. With the Creosotes, supplemented by additional quantities of tar acids.

3d. With the Creosotes, supplemented by some of the heavier portions of the same oils distilling over at a temperature exceeding 320° Centigrade (628° Fahrenheit).

4th. With the original Creosotes divided into the lightest, the medium, and the heaviest portions, with each of which the shavings were separately saturated.

A putrefying pit (*pourrisoir*) was prepared, in which the shavings were placed on the 10th of November, 1866, together with other shavings not prepared. After four years' sojourn in the *pourrisoir*, they were removed and ex-

amined on the 16th November, 1870. The results were strikingly in favor of the heavier oils, and adverse to the tar acids, which last bodies appeared to have been wholly ineffective. The shavings which had been prepared with the lightest portions of the oils, although they had contained the largest portions of the tar acids, were, nevertheless, in the worst condition. Those prepared with the oils somewhat heavier were in most cases better preserved. Best of all were the shavings prepared with the heaviest oils, procured by distilling at the higher temperatures even when containing no tar acids; these last were all perfectly sound. The un-creosoted shavings were all rotten. Mr. Coisne believed that the best portions of the oils were the "green oils," distilling at high temperatures.

These experiments are recorded at length in the "Annals des Travaux Publiques de Belgique," also in separate pamphlets. Their results have considerably influenced the practice of railway engineers on the Continent. The Belgian Government accepted the conclusions arrived at by Mr. Coisne, and for many years has based its creosoting specifications thereon, with highly satisfactory results. The specification for the Belgian State Railways does not stipulate for any tar acids; it requires that at least two-thirds of the Creosote must have been obtained by distillation at a temperature exceeding 250° Centigrade (482° Fahrenheit), and the remainder at a temperature exceeding 200° Centigrade (392° Fahrenheit). It allows 30 per cent. of naphthalene, which is calculated at the ordinary temperature. In a recent correspondence with the author, Mr. Coisne, who has for more than twenty years superintended the Creosoting operations of the Belgian Government, confirms the results of those experiments by his subsequent experience.

So far, the experiments and the experience of De Gemini, Rottier and Coisne appear to be in absolute contradiction with the theory that the Creosoting process owes its success to the tar acids. Yet the fact cannot be doubted, that the tar acids are powerful antiseptics, and that their presence arrests decay. What, then, is the explanation of this apparent anomaly?

The authorities on the tar acids are many and reliable. From amongst the learned and voluminous treatises which have been written respecting these bodies, fifteen references have been made to authors in England, Scotland, France, Belgium, Germany and America. None of them disagree as to the following facts: That carbolic acid is volatile at ordinary temperatures. That it is soluble in water. That its combinations are not stable. That it is a powerful germicide, but that its efficacy ceases so soon as it evaporates or is washed out of the substances intended to be preserved. Professor (now Sir Joseph) Lister, whose adoption of the antiseptic system for surgical purposes has revolutionized hospital practice, speaks from his large and valuable experience as to the importance of carbolic acid in the treatment of wounds, but he also remarks that its volatility is sometimes an evil as well as a good. Dr. Sansom, whose recent work on antiseptics so ably epitomizes the results arrived at by previous investigators, as well as those due to his own researches, speaks of it as the "aerial disinfectant" *par excellence*.

If this substance can be washed out by water, and if its volatility is one of its great merits, and occasionally a defect, for sanitary purposes, can it at the same time be considered as a durable agent amongst the oils injected into railway sleepers? Especially can this be the case in those tropical countries where extreme heat or torrential rains, or alternations of both, are prevalent? For piles and other timbers used for harbor-work, the comparative solubility in water of the antiseptic agents employed is also a matter of vital importance. What is true respecting carbolic acid, will also apply, to a great extent, to cresylic acid, the last substance being, however, somewhat less volatile and less soluble than the former. Do these bodies become stable by entering into combination with woody fiber? Their instability in this connection is apparently pointed out by Mr. Coisne's experiments. It may, however, be objected that these experiments were not conducted under the conditions to which railway timbers are exposed. This point also has been very fully investigated.

In 1867 Mr. Coisne obtained some Creosoted sleepers which had success-

fully resisted decay during periods of from eighteen to twenty years. The wood was crushed, and the substances obtained therefrom tested. He found no tar acids; if they had ever been there, they were no longer present. He found, however, a quantity of naphthalene; also of an oil which did not commence to distil until 230° Centigrade (446° Fahrenheit).

In 1882 the author caused some similar experiments to be made. Through the kindness of the authorities of the London and North-Western Railway Company, eleven pieces of old Creosoted sleepers were sent from their permanent way. They had been in use for the following periods:

1	specimen	16 years.
1	"	17 "
2	"	20 "
2	"	22 "
1	"	28 "
2	"	29 "
1	"	30 "
1	"	32 "

Sleepers were also received from the Taff Vale Railway, the South-Eastern Railway, and the Great Eastern Railway, which had been in use periods varying from fourteen to twenty-three years. A portion was also taken from a Creosoted pale fence, which had been fixed in the Victoria docks in 1855, and which is still in place, perfectly sound and strong, after twenty-nine years' use. A careful analysis of these seventeen specimens, all of ordinary Baltic fir, gave the following results:

1st. In no cases were any tar acids detected by the ordinary tests.

2d. In fourteen out of the seventeen specimens the semi-solid constituents of the tar oils were present; in twelve of them was naphthalene, this body being in some cases in considerable quantity.

3d. Only small percentages remained of oils distilling below 450° Fahrenheit. In the majority of instances from 60 per cent. to 75 per cent. of the total bulk of substances retained in the wood did not distil until after a temperature of 600° Fahrenheit was reached.

It is clear, therefore, that these timbers had been preserved by the action of the heaviest and most solid portions of the tar oils, and that the other constituents had disappeared.

4th. In some of these specimens acridine was searched for and detected. This substance is one of the alkaloids or bases now known to exist in the Creosote oils. This is probably the first occasion upon which acridine has been publicly mentioned in connection with the injection of wood; but the author is persuaded that it will come to be recognized as one of the most valuable constituents of the tar oils for timber-preserving purposes. It was discovered by Graebe and Caro; it is a powerful germicide, and solidifies within the pores of the timber, from which it neither evaporates nor washes out. It is intensely acrid and pungent.

Portions of the same specimens of wood, fifteen in number, were sent to Mr. Greville Williams, whose original researches with relation to coal derivatives have been for so many years known to the scientific world. Mr. Greville Williams tested the samples of wood for tar acids, naphthalene, and the alkaloids. For the tar acids he found all ordinary tests fail, until he employed the extremely delicate one by bromine and ammonia. In some cases, even by this test, no phenols could be detected, but in most cases he succeeded in detecting faint traces of those bodies; generally less than one part in three thousand; minute portions, probably of the heaviest particles of the tar acids which had been incorporated and retained by the heavier portions of the oils. It is needless to say that these infinitesimal quantities could be of no practical value in preserving the wood. In all the specimens, save two, he found naphthalene. The presence of the antiseptic alkaloids was distinctly proved, and one of these bodies, called cryptidine, which he had discovered in Creosote oils, in 1856, was detected by him in one of the specimens. Mr. Greville Williams concludes that the preservative action of the Creosote oils is due more to the bases or alkaloids than to the tar acids, as the former remain after the latter have disappeared. These researches were published in the "Journal of Gas Lighting," and also in a pamphlet in the possession of this Institution.

First, and most volatile of all the Creosote oils, are the carbolic and cresylic acids, which are also freely soluble in water at ordinary temperatures; they

come over from the still, incorporated with the lightest portions of the oils. Pure carbolic acid would entirely disappear by evaporation, if not secured in a stoppered bottle. Next in order comes naphthalene, which is much less volatile than the tar acids. It is not soluble in cold water, and almost insoluble in boiling water. As it comes from the still it is of a yellowish color, and mixed with the heavy oils, it gradually becomes black on exposure to the atmosphere. It forms the principal constituent of the thick, muddy-looking substance which sometimes forms on the surface of Creosoted timber, and which may often be seen adhering to the ends of railway sleepers for several years after they have been placed in the line. When sublimed by the action of heat and a current of air, it forms the beautiful frost-like substance well known in Creosoting yards. It becomes quite solid at a low temperature, and in that condition would be an impediment to the injection of the timber—a difficulty removed by heating the oils to about 100° Fahrenheit, at which temperature naphthalene becomes liquid. After injection it solidifies, and greatly assists in filling up the pores of the wood.

The following simple experiments, which have been tried and repeated in many different ways at the author's laboratories during the last few years, are in strict accordance with the now well-known characteristics of naphthalene and the tar acids:

1. If tar acids and naphthalene be separately exposed either at the ordinary temperature, or at the tropical heat of 130° Fahrenheit, the tar acids will evaporate with much more considerable rapidity than naphthalene.

2. Injected into timber the same results follow.

3. Light, thin oils, containing large percentages of tar acids, evaporate more quickly than heavier oils containing less tar acids and more naphthalene, when tested by methods Nos. 1 and 2.

In weighing after these experiments great care must be taken to allow for the absorption of moisture from the atmosphere. The tar acids absorb moisture before finally evaporating. Wood also absorbs a large amount of moisture when injected with oils containing these acids.

4. By repeated washings with cold water, all the carbolic acid, and all or nearly all the cresylic acid, can be washed out, both from country and from London oils. These experiments assume especial importance in considering the durable effects of various kinds of creosote for protecting timber immersed in sea-water from the attacks of marine insects.

Dr. Meymott Tidy has published the results of his experiments upon naphthalene. He injected pieces of wood with this substance, and exposed them to a temperature of 150° Fahrenheit. He found that the evaporation was only superficial, and that it practically ceased after forty-eight hours, the naphthalene below the surface remaining within the pores of the wood. Naphthalene is now recognized as an antiseptic, not so powerful in its immediate effects as the tar acids, but more durable. It is probable that tar acids of a heavier and less volatile type than carbolic or cresylic acids, may be more reliable as antiseptics for preserving timber.

Following in the series of distillates, amongst the Creosote oils are the alkaloids or bases of the quinoline or leucoline group, amongst which chemists are searching, not without fair promise of success, for a febrifuge similar to, if not identical with, the quinine derived from the cinchona plant. In this group occurs the substance called cryptidine, already alluded to as one of the valuable antiseptics discovered in those portions of the oils which were formerly characterized as "inert."

Para-naphthalene, mentioned in Dr. Letheby's specification, has since then become the basis of one of the most interesting chemical discoveries of the age. It was excluded by Dr. Letheby from the oils intended for timber preserving, and is probably without value for that purpose. It is now called anthracene, and is extremely valuable as the substance from which alizarine is manufactured, thanks to the brilliant discoveries of Perkin in England, and of Graebe, Liebermann and Caro in Germany. Alizarine is the coloring matter used by Turkey-red dyers and printers; for ages it had been extracted from the madder root. It is now made from the coal-tar product anthracene, of a far higher degree of purity, and at an enormously decreased cost. The madder root has gone

almost entirely out of cultivation. The quantity of anthracene contained in tar is relatively small.

Amongst the green oils, distilling between 550° Fahrenheit and 750° Fahrenheit, is found the acridine already alluded to as a valuable germicide and stable antiseptic. Phenanthrene, carbazol, pyrene, chrysene and benzerythrene, by no means complete the list, which is constantly being added to by new discoveries of the numerous bodies in which these dead oils are so prolific. The properties of many of these heavier bodies are still imperfectly understood; but from the fact that they will not evaporate except at exceedingly high temperatures, they are valuable ingredients for timber-preserving.

By the light of the evidence now accumulated, it may be advisable to review the question as to the relative value of these various bodies contained in the heavy oils as regards the preservation of timber. Some of them are becoming valuable for other purposes. Which of them should the engineer retain for injecting wood?

Can the conclusion be resisted, that for this purpose the efficacy of the tar acids has been overrated, and this at the expense of the more stable and enduring portions of the tar oils? The London oils as they come from the still are not sufficiently volatile to meet the exigencies of some modern specifications, nor do they comply with these exigencies as regards the percentage of tar acids. They do not, as a rule, contain more than from 4 to 7 per cent. of tar acids, and they will not yield 90 per cent. of their bulk by distillation below 600° Fahrenheit. Therefore a pressure is put upon the manufacturer to meet the fashion by "taking out" some of the heavier portions, and in some instances this is done. By this means the bulk is rendered lighter, and the proportion of tar acids to the diminished bulk is increased. For these heavier portions, especially for the green oils, a market is found for lubricating and other purposes. But in the author's judgment the efficacy of the oils as antiseptics for wood is thereby diminished. The green oils, after the anthracene has been removed from them by filtration, should be returned to the Creosote tank. The percentage of tar acids to be used remains a contested matter of opinion. But the author ventures to express the hope that at least the lighter portions of the tar acids, and especially carbolic acid, may soon be relegated altogether to their important functions as sanitary antiseptics, for which they are so valuable, instead of being wasted by the attempt to use them as antiseptics for timber, for which their peculiar properties render them unreliable. Upon the whole it would be wiser to revert, to a larger extent and with increased knowledge, to the plan of using the London oils mixed with the country oils, and encouraging instead of discouraging the use of the heavier portions. The whole of the Creosote oils manufactured from ordinary gas tar in this country are required for preserving timber, and to exclude one considerable portion of the supply is to enhance unnecessarily the cost of the rest. No oils, however, should be used as Creosotes which are lighter than water. Both bone oil and shale oil are sometimes offered as Creosote oils.

In 1881 Professor (now Sir Frederick) Abel and Dr. Tidy drew up a joint Creosoting specification, in which, as the result of direct experiment, they resolved to exclude no semi-solid bodies which completely melt at 100° Fahrenheit. They further changed the standard of volatility from 90 per cent. at 600° Fahrenheit to 75 per cent. Subsequent and prolonged investigation induced Dr. Tidy to go still further in the same direction, and not only to withdraw the clause limiting to 25 per cent. the oils distilling at a higher point than 600° Fahrenheit, but even to require that at least 25 per cent. of those non-volatile oils must be present. The author's experience leads him entirely to agree with the progress made in this direction.

CONFLICTING THEORIES ON PUTREFACTION—THE GERM THEORY.

If experiment and experience should lead to clearer views as to the relative value of various antiseptics, it may be advisable to test those views by reference to the recent development of theory upon the causes of decomposition in organized bodies. How do antiseptics act upon timber? Is the coagulation of albumen a sufficient explanation of their

preservative action? Surely not. Many substances, boiling water included, which will effectually coagulate albumen, will not prevent the decay of wood. Coagulation retards, but does not prevent, the decay of albumen itself. Again, the quantity of albumen in fir timber is exceedingly small, if the tree be cut down, as it generally is and always should be, during the season when the sap is not circulating. From a number of experiments made upon ordinary fir sleepers, the author arrives at the conclusion, that the quantity of nitrogenous matter or albumen which they contain does not usually much exceed 1 per cent. of their weight. Any watery fluid containing from 2 to 3 per cent. of tar acids would effectually coagulate this quantity of albumen. In some cases it is found that a portion of this albumen is actually coagulated by substances naturally contained in the timber. But the coagulation does not of itself preserve the wood. Leibig's theory of decomposition has already been alluded to. He maintained that putrefaction was due to eremacausis or slow combustion, produced by contagion, the infected bodies communicating a molecular motion to the atoms of the bodies with which they come in contact, and that these phenomena are not caused by the action of germs or living organisms.

The modern germ theory distinctly traverses this last assertion. Pasteur affirms, that without the presence of living germs, the phenomena of organic decomposition do not accomplish themselves, and that these germs are the veritable agents of the decomposition. The laborious experiments, and the lucid deductions of Professor Tyndall confirm the experiments and theories of Pasteur. Professor Tyndall explains that the air is laden with clouds of germs, agents of decomposition, ever ready to settle down and develop upon matter suitable to their growth. He finds that the contents of tubes filled with the most putrescible materials, animal or vegetable, can be preserved from putrefaction indefinitely, by the exclusion of germs. But that it is not sufficient merely to poison or neutralize one generation of organisms, the incursions of fresh myriads must be excluded, or putrefaction will ensue.

After reading the "Essays on the Floating Matter of the Air," in which Professor Tyndall describes how the germs gradually fell into the open tops of the test-tubes, let the comparison be made between the mouths of these tubes and the gaping orifice of a crack produced by the sun in a piece of timber. Through it the germs will descend, and if there is nothing to arrest their action, and if the crack is deeper than the portion of the wood charged with antiseptics, they will carry destruction into the center of the log. But if the antiseptic be of an oily or bituminous nature, it will flow into the cracks when they first develop themselves, and seal up the orifices against the enemy. Examine a crack or a wound in the trunk of a living fir tree; it will be found that by a natural process, a resinous substance exudes, which closes the wound against the agents of destruction.

The bodies of mammoths preserved in ice through countless ages, the trees of primeval forests excluded from the air beneath thick deposits of peat, the fragments of wooden piles which have endured undecayed for centuries when driven deeply below the surface of water, all confirm the experiments of Pasteur and Tyndall, and prove that the exclusion of germs prevents putrefaction. Specimens are exhibited of a wooden pile from the remains of the bridge (destroyed by fire) which was constructed by Charlemagne across the Rhine at Mayence; of pieces of piles from the foundations of the bridge across the Medway at Rochester, which was destroyed by Simon de Montfort in 1264, and which was probably then about one hundred years old; also from the new bridge erected to replace the former one in 1283.

It is not for the author to draw the dividing line between the decomposing action of germs and the action of oxidation. It is sufficient for his purpose to submit that all influences which either destroy or exclude germs, will prevent decay so long as those influences endure; but that permanent effects must not be relied upon from agents which are not themselves permanent and abiding. The germ theory then becomes a severe but a salutary test in choosing antiseptics for the treatment of timber.

Such treatment is of little value unless its effects will endure for long periods. Reliance, therefore, must not be placed upon those germicides, however potent, which will readily volatilize in air, or dissolve in water. A growing skepticism arises from experience as to insoluble compounds being formed between woody fiber and substances which are themselves soluble in water. In short, the substances to be employed should by preference be antiseptics in a double sense; they should be both germicides and germ excluders. From the long list of germicides must be especially excluded such as injure or weaken the fiber of the wood; amongst these latter must be classed all sōlutions with very strong acid or alkaline reactions; also some of the metallic salts. It has been seen, that the salts of zinc, mercury, and copper have been to some extent successful; of these the author's experience induces him to prefer sulphate of copper, as less soluble in water than chloride of zinc, and not volatile like corrosive sublimate. Even sulphate of copper cannot be permanently relied upon, when exposed to the continuous action of water; but it may be found useful in comparatively dry situations, or as a protection against dry-rot to timber under cover. From its properties as a germicide, sulphate of copper might be usefully employed in conjunction with oily or bituminous fluids, even with oils which do not possess great potency as germicides.

From all research and experience it would, however, appear that the same conclusions may be derived, viz., that the best antiseptics for timber are to be found amongst oils and bitumens which fill up the pores of the wood. Of such bodies, those which contain germicides are to be preferred. And, other properties being equal, those which either solidify in the pores of the wood or which require an extremely high temperature to volatilize them, and which are insoluble in water, must surely be the best of all.

Apparatus for Timber-Preserving.—Of the apparatus employed for applying antiseptics to wood, the most ancient and the most popular is the tar brush or the paint brush. During the last century, and in the earlier portion of the present, steeping in tanks was extensively adopted, the various liquids being employed either cold or heated. A marked improvement was introduced in 1831 by Mr. Breant, a director of the Mint of Paris, who invented the first apparatus for injecting timber by means of vacuum and pressure, in a closed iron cylinder; he employed, by preference, linseed oil and resin. The cylinder was fixed vertically, an inconvenient arrangement not necessary to the efficiency of his process. The iron cylinder and the process by vacuum and pressure were adopted by Mr. Bethell, and greatly improved by him and by Mr. H. P. Burt, who were associated together for some years. The cylinder was enlarged, its fittings strengthened and simplified, and an interior heating apparatus added. In Mr. Burt's paper of January, 1853, there is a full description of this machinery; its main features are still the same in the usual Creosoting apparatus of the present day. These cylinders, being of wrought-iron, were applicable to Creosote oils and to chloride of zinc, but not to salts having a corrosive action upon iron, such as sulphate of copper and corrosive sublimate. In 1842, Mr. Timperley described to this Institution a method which he had adopted on the Hull and Selby Railway, for lining the iron cylinder, in order to preserve it from the action of corrosive sublimate. This method and the expedient of smearing the inner surface with pitch were proposed and tried for sulphate of copper injections with but partial success. The author had several cylinders materially injured or destroyed by the corrosive action of these salts. In 1857 Messrs. Lege and Fleury Peronnet introduced an apparatus of which the cylinder, trucks and pressure pumps were entirely of copper, and machinery of this costly description is still used for the Compagnie des Chemins de Fer du Midi, at Labouheyre. In 1865 the author took out a patent for the following apparatus: Inside the iron cylinder he placed a wooden tank, which contained the timber to be operated upon, and in which was the sulphate of copper solution. It was an open wooden tank, inside a closed iron cylinder. The pressure applied was that of condensed air, a condensing air-pump being used, capable of maintaining an effective pressure of 200 lbs. to

the square inch. By this means the timber was injected with the copper solution without injury to the iron cylinder.

The process of Dr. Boucherie was at one time largely used in France. It consisted in the injection of newly-fallen timber in the forest by the vertical pressure of a column of the antiseptic solution, generally sulphate of copper, which was conducted through a pipe from a small reservoir fixed at a height of 30 or 40 feet. The tube was attached by an ingenious arrangement to the end or middle of the log; the antiseptic liquid expelled the sap from the softer parts of the timber, and took its place. The process is still used to a small extent in France, principally for telegraph poles.

Various attempts have been made to imbue timber with the vapors of oils, either by employing the tensions of the vapors themselves, or by the use of the pressure-pump. The first experiment of this kind appears to have been made by Lukin, in the dockyard at Woolwich in 1812, when the apparatus exploded, with fatal consequences to the workmen employed, and the attempt was abandoned. The patents of Franz Moll in 1836, of Bethell in 1864, and other subsequent patents, claim the invention of the principle of injecting Creosote oils in a state of vapor. If this could be conveniently or safely carried out, the system might possess some advantages. But there is a fatal objection to its employment. Timber is weakened by exposure to a temperature much exceeding 250°Fahrenheit, whilst at 300° Fahrenheit, or a little above, it commences to decompose, and becomes seriously injured. Now the boiling point of the Creosote oils ranges from a little below 400° Fahrenheit up to 760° Fahrenheit. As with the steam of water, so is it with the vapor of oils—no pressure can be obtained with them, except at a temperature exceeding their boiling point. The vapors of the Creosote oils cannot, therefore, be injected into timber except at temperatures, and under conditions of pressure, which would destroy the value of the timber as an engineering material. The process has been tried in France, and it failed, owing to the complete deterioration of the timber.

A modification of this system has, however, been carried into practice. Super-heated steam was passed through Creosote oils, and then injected into the sleepers (which had been previously warmed by steam) with the idea that the mingled vapors of water and Creosote might be injected into the timber at a temperature of from 290° Fahrenheit to 320° Fahrenheit. With this modified process, the author's firm carried out some extensive operations for the Compagnie des Chemins de Fer de l'Ouest, it being the desire of the engineers of that company to economize the Creosote, and to try whether in a finely divided state, a smaller quantity might not suffice by being more deeply injected. The operation was supplemented, however, by an injection of Creosote in the usual fluid state.

After prolonged trials, the first part of the operation was discontinued by order of Mr. Bouisson, the company's engineer of the permanent way. It was found, whenever the cylinder was opened before the second operation, that a small portion of the lightest particles of the Creosote had been carried over mechanically into the cylinder by the superheated steam. Once within the cylinder, however, the two fluids obeyed the laws which govern their respective volatilities: the Creosote oil sank to the bottom of the cylinder, and the vapor of water only was injected into the timber. The sleepers on examination and testing by the ordinary tests, contained neither tar oils nor tar acids.

An analogous experiment tried at the Timber Preserving Works of the Austrian North-West Railway, is described in the journal of the Architects and Engineers' Institute of the Kingdom of Bohemia for 1880, by Herr J. Seidl, and the process has been condemned for very similar reasons.

Condition of Timber at Time of Preparation.—Getting Rid of Moisture by Stacking or Artificially.—The hygrometric condition of timber at the time of injection is an important element in the success of the operation, all important with the Creosoting process especially. Neglect on this point has often been the cause of partial or total failure. Woody fiber in itself is heavier than water, its specific gravity being generally considered as equal to 1.5, water being 1.0. It is, therefore, owing

to the looseness of their texture, that so many kinds of timber are lighter than water. The specific gravity of fir timber varies ordinarily between 0.5 and 0.8; the difference arising as often from the varying density of the timber itself, as from the quantity of water contained. As fir timber can, under certain conditions, absorb so much moisture as to become water-logged, or actually heavier than water, its powers of absorption can be calculated from its specific gravity. It can take up as much as from 60 to 150 gallons of water to the load of 50 cubic feet, the maximum quantity being, of course, an exceptional possibility. Fir and pine, however, frequently contain as much as from 15 per cent. to 20 per cent. of water, after from two to three years' stacking. The question of the pernicious effects of an excess of moisture in the timber at the time of Creosoting, has been from time to time brought before this Institution by Mr. Bethell, by Mr Burt and by the author. Large logs taken out of timber ponds, or sleepers freshly imported, are not in most cases in a fit condition for Creosoting until after having been stacked for from four to six months. The author, in common with most of the earlier operators in this process, has tried various methods for artificially drying the timber. Steam, ordinary and super heated, currents of hot air, and drying stoves or ovens, have been used for this purpose, but have all, in this country, been abandoned. To subject timber to a dry heat, elevated enough to remove its moisture with the necessary rapidity, will invariably result in injury to the wood. Timber piles stoved before Creosoting, prove brittle when driven. The action of the air-pump in the ordinary process assists the operation by withdrawing air from the pores of the wood; but it is a mistake to suppose that it has much effect in withdrawing moisture.

These difficulties have perplexed the author for many years. He has recently devised a method by which to get rid of the moisture as part of the timber-preserving process, and without injury to the wood. An experiment easy to reproduce, and which explains the nature of this operation, is made as follows: An ordinary glass flask, in which are placed some pieces of wood saturated with water is connected by glass tubes with an experimental air pump. By working the pump the air is extracted from the pores of the timber, but however efficient the vacuum may be, no perceptible moisture is withdrawn, nor would the water be removed from the wood except by a slow evaporation prolonged beyond practical limits. This represents the ordinary action of the air pump upon timber in a Creosoting cylinder. If sufficient heat be now applied beneath the flask, the water will become volatilized, and will be withdrawn rapidly in the shape of steam by the action of the air pump. But the wood will be found to crack, and open to an extent which is not desirable. This illustrates the result of applying dry heat.

Now take a similar flask with a condensing apparatus added; moreover, the flask should contain Creosote oil, in which the wet timber is submerged. It must be constantly borne in mind that at the ordinary tension of the atmosphere, the boiling point of the Creosote oils ranges from about 380° Fahrenheit to 760° Fahrenheit, as compared to water at 212° Fahrenheit. These boiling points are, however, lowered, according to a well-known law, by the effects of a vacuum. Let the Creosote in the flask be now heated to 212° Fahrenheit, whilst the air pump is put into operation. The heat being communicated through an oily medium will not injure the timber, from which the water is volatilized, and drawn out by the air pump. The Creosote oils are not volatilized, as the temperature is far below their point of ebullition. The water is speedily and effectually removed, and the Creosote takes its place.

By the ordinary and well-known process, after the timber has been placed in the cylinder and the air-tight door closed, the air is exhausted from the cylinder, the Creosote is then introduced heated to a temperature of from 100° Fahrenheit to 120° Fahrenheit, when the air pump ceases to work, and the pressure pump is put into operation.

Referring now to the new process, it will be seen that a large dome is placed on the top of the cylinder, to which the exhaust-pipe of the air pump is attached. The exhausting process is continued after the Creosote has been introduced into the cylinder. The Creosote during

this part of the operation should not be allowed to rise quite to the top of the vessel, a free space being preserved, and the dome kept empty, so that the Creosote is not drawn through the exhaust pipe. The Creosote is raised to a temperature a little exceeding 212° Fahrenheit instead of 120° Fahrenheit as heretofore. The exhausting process is continued until all the water is extracted from the timber in the form of vapor, drawn through the dome, condensed by passing through the worm of the condensing apparatus, and collected in the receiving tank, where the quantity extracted can be measured. With charges of very wet sleepers, the author has succeeded in withdrawing water equal in volume to 50 gallons per load of timber, and replacing this water with an equal volume of Creosote by the action of the air pump alone. If necessary, however, the pressure pump can be afterwards applied in the usual way.

A slight additional cost, and a few hours' additional time are necessary for dealing with very wet timber by this process as compared with the ordinary method. But the expenditure in time and money is not so great as would be required by stoving the wood before Creosoting. If, in the absence of artificial methods, timber be stacked for six months, as it should be, the interest on capital represents a certain expenditure also. The author ventures to suggest that this is not always taken sufficiently into account, in giving out contracts for creosoted timber. Other conditions being equal, dry timber is at a disadvantage in the competition, as far as price is concerned, with timber just landed. Yet a small extra expenditure in this particular would frequently be repaid to the consumer twenty or thirty-fold in the prolonged duration of the wood.

Conclusion.—In conclusion the author would remark that with regard to certain points mentioned in this paper, upon which some controversy has at times arisen, he has been careful to advance no opinion which he has not confirmed, either by the opinions and investigations of eminent authorities, or by careful and reiterated experiments. Many hundreds of experiments have been in fact carried out at the laboratories of the author's firm at Silvertown during the last five years, with the especial object of investigating the properties of the tar oils and other antiseptics, and their behavior in contact with timber. To Mr. Royle, Mr. Bendix, and Mr. Holmes of the chemical staff of his Silvertown Works he has to return his best thanks for their skilled assistance, and particularly to Mr. Bendix, who has been more especially entrusted with the conduct of these experiments. To Mr. Gabbett he is indebted for the drawings exhibited.

The Treatment of Timber by Antiseptic Methods has been acknowledged by some of the greatest engineers of this country to have been useful to the art of constructive engineering. It may be made even more useful in the future than it has been in the past. All that the advocates for its still more extended development can desire to claim will be, that their methods and investigations may be seriously examined, and from time to time decided upon, in accordance with the results which science and experience may bring to light.

THE CLYNDOGRAPH.—The clyndograph of M. Moessard is a new panoramic photographic apparatus, which by a simple rotation of the objective gives the cylindrical perspective of the earth. A view furnished by the apparatus embraces an angle of 170°, so that a complete turn of the horizon is obtained in two views and a fraction of 20° range. The instrument is based on the principle that a lens or combination of lenses, constituting a photographic objective, may be subjected to any movement whatever without the image it produces on a screen changing its form or position, provided that the movement takes place around the nodal point behind, which is maintained immovable. This follows from the known property of the nodal point being the point of view of the perspective produced. Suppose, then, there be (1) an objective suspended horizontally and turning round a vertical axis passing by its after nodal point; (2) two vertical shutters fixed behind to right and left of the objective, to limit the field in the horizontal direction and arrest rays too oblique; (3) a screen, of cylindrical form vertically centered upon the axis of rotation, and having for radius the distance of the nodal point from the principal focus of the objective. In any position whatever of the objective the lie of the country comprised in the field of the instrument will be projected on the screen. If the objective be put in motion one gets successively for each point of the panorama an immovable image which impresses the eye or sensitive paper whilst the point remains between two shutters. In M. Moessard's actual apparatus Thiebaut sensitive plates are used to receive impressions.

THE PROPERTIES OF MALLEABLE IRON, DEDUCED FROM ITS MICROSCOPIC STRUCTURE.*

From "Iron."

ALTHOUGH there can be no doubt that the chemical and physical properties of iron are closely connected, the one cannot, however, be directly deduced from a knowledge of the other. This deduction may be performed with the most certainty in the case of pig or cast iron, which possesses but a low degree of toughness, while the difficulty increases with the decrease in the percentage of carbon, and the increase in tensile strength and ductility. In the case of malleable irons (steel and iron, ingot and weld steel and iron), previous experiences have shown that no basis exists on which the connection between chemical and physical properties may be determined with even the slightest degree of certainty. Even the attempts to determine, from their chemical composition, how rails will behave during use, have been entirely unsuccessful. Indeed, rails which are made by the same metallurgical process from the same material, and of the same chemical composition, do not present the same properties, although they are throughout apparently homogeneous. This is even more the case when any of the different varieties of iron occur together—as, for example, in the case of compound armorplates; or when similar varieties of iron are produced by different processes—for example, soft forge pig iron, open-hearth iron, and Bessemer iron from acid or basic converters. All these varieties of iron can have a perfectly identical chemical composition, and yet behave entirely differently on working and in use; and also, after quite similar treatment by hammering, rolling, &c., behave in an entirely different manner from that expected when submitted to tension, pressure and percussion.

Impossible as it is to say from the chemical composition found by analysis what the physical properties are, it is equally impossible to deduce the chemical composition from the physical properties, for example, from the tensile strength, elongation, and contraction obtained on testing. Frequently, too, the results of the tests of tensile strength, elongation and contraction are not even sufficient to explain the behavior in use. It has frequently been observed that rails of ingot iron possess the peculiarity of unexpectedly breaking on being suddenly cooled, or on being exposed to a very low temperature; while rails of weld iron, possessing chemically the same composition, and mechanically the same tensile strength, elongation and contraction, or even when they have given more unfavorable results, remain unaltered. The inconvenience of a sudden fracture of an apparently perfectly sound ingot-iron main shaft of a screw steamer, has in many cases led to the preference being given to an intrinsically inferior one made of weld iron.

In order to explain these contradictions, and to fill up the apparent gaps in the scientific metallurgy of iron, recourse must be had to the microscope, which reveals properties that cannot be discovered either by an analysis or by mechanical tests. The investigations conducted by me, which I here present by the kind invitation of the President of the Iron and Steel Institute, my friend Dr. John Percy, have not in any way exhausted the subject. They are but the commencement of the path into a wider field of research, and are intended to serve merely as an inducement for followers in the same path. Microscopic investigations of iron have long been made, but only systematically in a few cases. The most complete are the investigations of pig iron, especially the researches of the present Manager of the Royal Prussian Mechanical Testing Institute, Mr. A. Martens. He has devised a very satisfactory method of distinguishing the separate constituents of a piece of iron by etching and tempering. He has also, at my request, prepared for the Royal Mining Academy of Berlin a collection of 120 sections, upon which the following investigations are based.

* A paper read before the Iron and Steel Institute by Dr. Wedding.

Besides these, several test pieces from the well-filled museum of that institution were also examined. The sections are prepared in the following manner: The small test pieces, obtained from the main iron mass by breaking, planing, filing or crushing, are first ground in a grinding machine with a coarse emery wheel, and are then evenly and finely ground upon cast-iron plates on which emery is spread. Coarse emery is first employed, and is replaced by finer and finer emery as the grinding proceeds. The pieces of iron are then fastened with a cement of resin and wax to a thick piece of looking-glass. In order to guard againt the removal of the cement during the grinding by becoming hot, water is added. The polishing is then effected by hand, with polishing agents washed as carefully as possible, such as ferric oxide, putty powder, tripoli, &c. The polished section is then etched with very dilute acid; for this purpose, platinum chloride, nitric acid, hydrochloric acid, acetic acid or salicylic acid is employed. A mixture of tincture of galls and acetic acid is also used. After the etching, the section is carefully heated, whereupon the portions attacked acquire varying tints, mostly golden yellow, purple, red, violet, or dark blue. A subsequent faint gilding has also been employed by Martens. It must be borne in mind that it is not the colors that are characteristic, but their differences. In each section of my paper I give the reasons for the conclusions which I have drawn from my investigations—reasons which, with proper judgment, may be easily deduced by any observer who wishes to continue the investigations on the same basis.

FORMATION OF GRAINS AND FIBERS.

Iron, in a pure state, as well as in combination and mixture with the amounts of amorphous carbon, silicon, phosphorus or sulphur which occur in a wrought iron of technical value, and with a small percentage of manganese, crystallizes in the regular system. When it is possible for crystals to form freely in cavities, the crystals present an octahedral form, resembling a pine tree, with an embodied development of the crystal axes. In the compact iron mass, on the other hand, the individual crystals do not become complete, but press one another, and form grains which are, for the most part, bounded by pentagonal planes. Evidence of this is afforded by each section of a test-piece of iron that has been allowed to cool quietly, and without being disturbed by external pressure, from the fluid or viscous state of aggregation, but is equally obtained in iron produced by an oxidizing process from pig iron, or by remelting. The size of these grains, which, as they belong to the regular crystal system, appear, when the piece of iron is broken, to be on all sides of the same form, and of the same size, is dependent upon two circumstances—firstly, on the rapidity of the cooling; secondly, on the nature and amount of the other elements, either admixed or chemically combined with the pure iron. In the case of malleable irons, the presence of graphite ought, as a rule, not to be taken into account; it is present more especially in the varieties of steel rich in carbon, but in the malleable irons in practical use it occurs only exceptionally in such amounts as to interfere with or influence the formation of grains, as always in the case of gray pig iron. Other things being equal, the size of the grains increases in proportion to the slowness of cooling. On the other hand, the size of the grains decreases, with the same kind of cooling, with the proportion of carbon up to 2 per cent. Above this amount, when the percentage of carbon rises or falls, the grains increase in size. Silicon, sulphur, and small amounts of manganese, titanium, chromium, and tungsten, favor the smallness of the crystals, whilst phosphorus increases their size. Evidence of this is best afforded by pieces of crucible cast steel containing various amounts of carbon, or containing the same amount of carbon and varying amounts of the other substances mentioned. In this case the microscope is hardly necessary, for even the naked eye can detect the truth. In tungsten steel, containing 2 per cent. of carbon, an almost amorphous fracture is exhibited.

The only element that changes the regular crystal form of iron containing carbon into a rhombic, or, as the end faces have not with certainty been determined as in right angles, into, at any rate, a crystal form not belonging to the regular system, is manganese in consid-

erable quantities. It is not astonishing that inconsiderable amounts of manganese effect no change. An analogous phenomenon is frequently observed in the crystallization of salts from aqueous solutions, in which small quantities of other crystallizing substances effect either no change, or but an inconsiderable one, in the form of salt crystals. As soon as manganese occurs in large quantities, from 2 per cent., according to my investigations, the regular crystal form of the iron is changed. This may easily be seen in the case of pig iron; from granular iron a radiated white iron is obtained; with a larger percentage of manganese, foliated spiegeleisen; and with a still higher percentage of manganese, columnar ferromanganese is got. Malleable iron with more than two per cent. of manganese occurs only in unsuccessful Bessemer castings. Under the microscope, too, it is difficult to detect the influence of manganese, as the crystal grains, described later on, appear to acquire only, when the percentage of manganese increases, a long columnar form. At all events, these influences may be better detected, as also in the case of pig iron, with a larger field of vision under a magnifying glass than with the microscope. Each individual grain in malleable iron is ductile. The malleability of the entire piece of iron depends upon the ductility of the separate grains.

If pressure is exerted on an individual grain in the direction of but one axis, as occurs, for example, when a piece of iron is hammered on an anvil, there is formed from the round, or, more correctly speaking, many-sided grain, bounded by pentagonal planes, a plate technically known as "scale" (Schuppe). If, on the other hand, the pressure acts in the direction of two axes, either at the same time, as in the case of rolling with a diagonal groove, or at different times, as in the case of hammering an ingot or rolling a bar, turning it round 90° after every passage through the rolls, the grain is converted into a column, which belongs apparently to the tetragonal system, and which is, in practice, termed a "fiber' (Sehne). Fibers are thus elongated grains. Confirmation of this assertion may be obtained under the microscope with sections cut from rough and worked pieces of iron, partly parallel, partly at right angles to the plane of pressure. The phenomena are, for reasons that are explained below, most distinct in the case of quite soft weld iron rich in slag. In sections parallel to the fibers the separate columns may be very clearly followed, while in sections at right angles to the fibers no elongation is noticeable. This fact explains why a fracture at right angles to the fibers appears granular to the naked eye. A fiber cannot, however, extend in any possible length without again breaking up when given conditions are brought into play. The percentage of carbon has the greatest influence on this phenomenon. If the percentage reaches or exceeds 0.5 the fibers split up into grains, even with slight stretching. The same effect is produced also with a low percentage of carbon by a very small amount of phosphorus, a large amount of silicon, or a not inconsiderable amount of sulphur.

Under such circumstances the fibers, on being stretched, split up into grains, which must always be smaller than the grains from which they originated. This phenomenon is better shown under the magnifying glass than under the microscope, as the field of the latter is not large enough to show several grains at the same time if they are not very minute. The fact that steels rich in carbon, and finely granular iron (Feinkorneisen), form no fibers, is well known in practice. The formation of grains by phosphorus is so characteristic, that it is employed for detecting very small amounts of this element in basic Bessemer iron. Moreover, this fact shows that from a fibrous iron a coarsely granular iron cannot be formed by any influence, with the exception of elevated temperature. The theory of a conversion of this kind by means of faint concussions must consequently be relegated to the domain of fable. The fracture of a fibrous iron can only exhibit a grain equal to the section of the fibers, or a finer grain when, through concussion, an elongation has been effected. This is confirmed, I may add, by the experiments of Wobler and Spangenberg.

CONDITIONS FOR THE FORMATION OF FIBERS IN IRONS POOR IN CARBON.

Although iron poor in carbon is alone adapted for the formation of fibers, yet every iron poor in carbon, when com-

pressed in the direction of two axes, does not form fibers. It is a known fact that weld iron, during the rolling process, very easily forms fibers, but that ingot iron very rarely does so. The reasons for this remarkable phenomenon are also explained by means of the microscope. Microscopic examination of sections of fibrous iron parallel to the direction of the fibers, shows that the individual fibers form wires which lie parallel to one another. But they never, even in the case of the softest weld iron, have a very long extension, but always give place to new fiber heads, which rarely lie in the same direction, being generally more or less displaced, though always parallel. From this it may be concluded that the strength of fibrous iron depends on the fact that, like the individual hemp fibers in a rope, the fibers lie with their ends in various sections. The microscope shows further that none of these wires or fibers is directly connected with its neighbors, either in a lateral or longitudinal direction. In fact, each fiber may, by careful etching, be picked out like those of a muscle of the human body. On examining into the cause of the separation of a fiber from those immediately surrounding it, a separating intermediate layer is distinctly observed. This intermediate layer is composed of slag or iron scale (Fe_3O_4). These intermediate layers accompany the fibers, in every case, as far as their ends, and there surround the fiber heads as a very fine envelope, either joining the following fibers, or undergoing a short disconnection. In the latter case a granular structure immediately occurs at the point in question, that is to say, an agglomerate of crystals may be seen, which are shifted towards one another and intimately entangled.

This latter phenomenon is so frequently the rule that, with a small field and a high power, and with a section parallel to the fibers, the observer imagines that he is looking at a granular iron, while with even a slight shifting of the object in a longitudinal direction, the elongated crystals again appear as fibers. Just as this phenomenon of grain formation between the fibers only occurs when no separating slag envelope is present, in the same way in the formation of fibers the slag envelope is never wanting. From this it must be concluded that the formation of fibers does not take place without the admixture of slag. Proof of this is afforded by the results obtained with the Bessemer process on a small scale at Avesta, in Sweden, where a perfectly fibrous ingot iron was produced in the Bessemer process by an intentional admixture of slag. Further proof is afforded by the tests to determine whether the iron, in the basic process, is free from phosphorus. The iron, which is ladled out for the test, is mixed with slag, and consequently, when under the hammer, the formation of fibers is effected, which gives a silk-like structure to pure iron, in contradistinction to iron containing phosphorus, which remains crystalline. By this means it may very easily be seen whether the iron is free from phosphorus. Moreover, the microscope shows that the slag portions in fibrous iron are intimately mixed with the iron, since, even within the separate fiber skeins, portions of slag may, with a sufficiently high magnifying power, be always discovered. Varieties of iron that are very free from slag, as, for example, crucible cast steel, are hence the most averse to the formation of fibers.

CONSTITUTION OF THE INDIVIDUAL IRON CRYSTALS.

While, under the microscope, weld iron is very suitable for the study of the formation of fibers, it is, on account of the slag mixed with it, unsuitable for the investigation of the grains and the individual iron crystals. For the latter, ingot iron alone is quite suitable. In the microscopic examination of the various varieties of iron, the only variety appearing approximately homogeneous, and composed of grains of the same size, is crucible cast steel that has cooled comparatively quickly. In all other varieties, even in test pieces from large, and therefore slowly set, ingots of cast steel, on etching the thin section, two different varieties of iron are exhibited, one of which is interstratified in the other, by which it is in a manner surrounded, so that the smooth cut plane of fracture acquires a porphyritic appearance. The closer the iron approaches to raw iron, that is to say, to the original state in which it was produced, the more distinctly do the two kinds of iron separate from each other, and exhibit a network

enclosing angular bodies. In the following portion of my paper the angular inclusions are termed crystalline iron, while for the iron forming the network the term homogeneous iron is reserved, merely for the sake of clearness and brevity. The form of the crystalline iron bodies is that of regular polygons, only in the interior of iron ingots that have cooled uniformly. In other cases the crystalline iron bodies are, as a rule, extended in one direction, and this longer axis is at right angles to the cooling surface in the case of iron simply set, and not submitted to any subsequent treatment. In the case of pieces of worked iron, on the other hand, it follows the course of the homogeneous iron portions, or corresponds to the axis that is not compressed—generally the longitudinal one. Bodies of this kind often occur together, and thus give rise to forms resembling letters, and apparently quite irregular. These forms, however, under a sufficiently high power, may always be further split up, exhibiting the manner in which they are formed of single regular bodies. The crystalline iron bodies occur the more frequently, but, at the same time, of smaller dimensions, the more closely the proportion of carbon approaches the limit of 2 per cent. In soft iron, low in carbon, they are often widely separated from one another, but are of considerable size. The crystalline iron bodies of the latter kind appear to consist again of various parts. The impurer the iron investigated the more they exhibit surfaces not unlike that of a checkered cloth. On the other hand the homogeneous iron forming the network is very uniform, even when seen under a very high magnifying power.

It is remarkable that the homogeneous iron is sometimes harder and sometimes softer than the crystalline iron. If the iron has been produced by a decarburizing process, it is softer. If the iron (as for example, cement steel) has been produced by a carburizing process, it is harder. This may easily be seen from the fact that, with etched test-pieces of the former kind, the network is depressed from the surface, while in test pieces of the second kind the network projects from the surface. Hence, the homogeneous iron appears to be the conductor of oxidation and carburization, by which means a molecular change to crystalline iron is effected. If these phenomena have been made sufficiently clear from the study of ingot iron, the same may also be discovered in the case of weld iron. Here the homogeneous iron passes through the iron mass, frequently like leaves, in a direction inclined to the axes of the fibers, forming, to a certain extent, the cement between the fiber bundles. An explanation of these phenomena, hitherto studied but little, if at all, can only be found in the want of uniformity in the iron. Obviously, particles of the same kind collect together and separate out in the remaining mass that is still fluid. For the present it is, however, not clear why the homogeneous iron, which apparently represents a pure metal, forms the ground mass that remains fluid to the last; as one might be inclined to assume that, as in the puddling process, the grains of pure iron separate out first and are drawn through or surrounded by the impure fluid iron mass. This phenemenon consequently requires further investigation. It might, perhaps, be possible, by careful etching of large masses of iron, to dissolve sufficient material for an analysis.

WELDING.

The scientific explanation enunciated by me some years ago that welding represents the transition from adhesion to cohesion has been somewhat generally adopted as a satisfactory one. This explanation, however, has been considerably modified by the results of microscopic investigation. The fibers of weld iron are situated like parallel wires in a bundle of wire, only connected by slag, or, better, separated by slag; but where the fibers are replaced by grains, the homogeneous iron again occurs surrounding them, or, at least, flowing through them. The corners and bends formed by the homogeneous iron increase in proportion to the size of the crystals, and this explains, as is shown by the microscopical examination of cold short iron, the weakness of iron containing phosphorus. In the case of ingot iron, on the other hand, the homogeneous iron forms an evenly surrounding layer around the crystalline iron, and forms, in this manner, the connecting mass, so that the fracture of a very finely-granular steel

resembles in every way that of an amorphous substance, such as glass, although the individual crystal grains produce the roughness of the fractured surface. The greater irregularity of ingot iron, corresponding to the distribution of the two varieties of iron it contains, as compared with weld iron, does not, however, prevent the mass of the metal showing, on the whole, a greater resemblance to a homogeneous substance than weld iron does. This fact explains the greater tensile strength of ingot iron as compared with weld iron. In the case of the latter, traction acts separately upon each individual fiber, just as it would upon each individual wire contained in a bundle of wires. When the limit of elasticity is passed, each fiber stretches separately, and breaks on passing the limit of resistance, the consequence being that weld iron breaks gradually and not suddenly. In the case of ingot iron the grains stretch independently, and change their relative positions without, however, losing their connection with one another, which is produced by the homogeneous iron, until the limit of resistance is reached; then, however, the fracture is a sudden one. This property of ingot iron is, if properly applied, an advantage as compared with weld iron, and not a disadvantage, as is supposed by many engineers, who find it impossible to break loose from old-fashioned ideas.

The uniformity of ingot iron as a whole is only interrupted by the presence of blowholes. It is a well-known fact that it is impossible to produce castings of ingot metal which are entirely free from blowholes. The difficulty increases in inverse proportion to the percentage of carbon. Again, it is well known that the formation of blowholes may, to a considerable extent, be prevented by allowing the metal to stand quietly, by pouring at a definite temperature, by the addition of silicon, &c.; or that, by the application of pressure, a uniform distribution of the blowholes may be effected. The microscope, however, shows that blowholes never disappear entirely, although they are to a great degree eliminated in the case of crucible cast steel; they are most abundant in Bessemer steel, open-hearth steel holding an intermediate position between the two. The blowholes appear to be always surrounded by homogeneous iron, and never to occur in the crystalline variety, nor even to pass through the crystalline iron bodies. The microscopic examination of blowholes occurring at some distance from the surface of an ingot iron casting is of some interest. The connection of the external layer of the casting with the internal portion is, in this case, always represented by a network of homogeneous iron, never by the crystalline iron bodies which occur as elongated, distinctly-defined curves placed perpendicularly to the cooling surface, while continuous veins of the homogeneous iron may be traced from the edge to the interior.

What I have hitherto stated refers to the connection or welding together of the parts of iron in the case of one piece. It is somewhat different in the case of *two* pieces of iron which have been welded together. In this latter case the joins are always discernible. In weld iron, however, at the point where two fibers of the two separate pieces simultaneously cease, it is evident that there has been a mingling of the crystals. There are probably those points which appear crystalline when a weld seam is torn apart, and in which the adhesion of the two pieces of iron has really changed to cohesion. It is different in the case of two pieces of ingot iron. In this metal the joins can always be traced. It is true that the crystalline portions of the two piece, after being worked considerably, are pressed into one another, and consequently hold together somewhat like hooks; but the homogeneous iron, which always occupies the surface, appears never really to combine. From this it may be concluded that, for a true welding of ingot iron it is necessary to heat the metal almost to its melting point. This explains the imperfection of all ingot iron welds, and it would be better for engineers to avoid entirely all welds of this kind, and to replace them by iron suitably shaped. It also explains why a very soft ingot iron containing slag may be welded just like weld iron. The strength of a finished piece of iron depends on the sectional area of the mass of iron it contains. From the total sectional area of a piece of weld iron the slag inclusions, and, in the case of ingot iron, the blowholes must be deducted.

This calculation is decidedly in favor

of the ingot iron, though it can only be superficially effected, even with our present knowledge of microscopy.

CONCLUSION.

However inexhaustive my observations may have been, seeing that the examination was confined to, at the most, a few hundred microscopic sections, still I trust that they have yielded interesting explanations, or, at all events, suggestions; and it would afford me much pleasure to have an opportunity of showing, in Berlin, to the members of the Iron and Steel Institute, proofs of the statements made in my paper.

Sir Henry Bessemer—With regard to the crystallization of iron or steel that had undergone fusion, very different results were obtained according to the size and form of the crystals, and this again was dependent upon the perfect stillness or otherwise of the mass under operation. In England the crystallization of sugar was allowed to go on unobstructed, and, therefore, large and distinct crystals were formed; whereas in France it was stirred during the crystallization, and so an amorphous mass of saccharine was produced, and the crystals were less bold and distinct. Nearly thirty years ago he was anxious to see how the presence of phosphorus affected crystallization, for he suspected that the large crystals from which his process at that early period was suffering were due to the presence of that deleterious element. He determined to allow the mass to cool as slowly as possible, and for that purpose he had a large hole made in the ground four feet in diameter, lined with brick. A charcoal fire was kept in it for three or four days, and when it was heated to a white heat a mass of Bessemer iron, wholly decarbonized, was poured into it. It was then covered with hot sand, so that the escape of heat was rendered almost impossible except by slow percolation. At the end of five or six days the mass was taken out and allowed to cool, and he found that a piece 15 inches in diameter was readily broken through by a single blow of a large hammer. By taking it in one hand and striking it with a 2-lb. hammer he could detach showers of crystals. The cohesion of the mass had been rendered almost *nil* by the perfection of the crystals. Some of them were cubes of nearly the size of common dice, and were beautifully polished and white. They could be hammered out into discs as large as a sixpenny piece, showing that the metal was malleable, and it owed it excessive weakness only to the perfect crystallization which had been encouraged by that particular process. That, perhaps, was one of the points which practical men would, with a little consideration, no doubt apply in some shape or other. It was quite impossible, when iron was produced in a malleable state, and recarburetted by putting very highly carburetted metal into it, that the simple pouring of these two elements together could produce a homogeneous mass. In every ingot of ordinary iron or steel there were strata of the malleable iron mixed with the carbonizing metal, and it was only by a thorough admixture of those parts before casting took place that they could hope to get anything like a homogeneous result. Even that, as Dr. Wedding had shown, was not sufficient to prevent the formation of different kinds of crystallization, as though some particles elected to form crystals of themselves, and, having abstracted certain atoms to form that crystal, they left in their immediate neighborhood and surrounding them another compound of iron containing more or less carbon than the central nucleus was formed of.

Mr. Bauermann regretted the absence of illustrations of the structures described in the paper. A Russian observer had stated that in all he had examined the crystals belonged to the cubic system, but Professor Malliard, of the Ecole des Mines, Paris, stated that the cubic form was retained only up to when the alloys contained less than 50 per cent. of manganese. The paper stated that by rolling the grain was converted into a column belonging apparently to the tetragonal system. It would, therefore, seem that it was not a really crystalline change, but something analogous to what took place when any homogeneous material, such as glass, was strained.

ACCORDING to the census returns of 1881 the Civil Service employed 50,245 persons, and the police 32,508. Soldiers, with yeomanry and militia number 87,168.

—*The Engineer.*

RENDERING WOOD FOR BUILDING PURPOSES NON-INFLAMMABLE.*

By THOMAS MANSON RYMER-JONES, M. Inst. C.E., F.R.G.S., and JOHN RYMER-JONES, M. Inst. Tel., Eng.

From "The Building News."

The rendering of wood for house construction non-inflammable should be a subject of great interest to all. There is, however, little information obtainable from published works. The Japanese light structure is, perhaps, a necessary evil, but also has its advantages, and the Japanese would probably be unwilling, either from conservative feelings or from a question of expense to build more costly, durable and fire-proof houses. Let us see, then, how these wooden buildings may be preserved from destruction by fire, though the cost in the more thorough processes may be possibly sufficient to preclude their use among those whose poverty is the reason for their not building more durable houses. Secondly, it must be remembered that an individual house, though it would not burn by itself, yet if surrounded by a conflagration of the adjacent buildings would smoulder away, though it would not burst into flame. Hence, it is necessary that a block or small number of prepared houses should be together, in which case only those nearest to the advancing fire would be damaged and all the rest remain intact. This might be done by Government order, private agreement amongst themselves, or a fire insurance company, who would take insurances on any block so prepared at moderate rates. Let us then proceed to pass the various processes in review, with their advantages and disadvantages fully set out, and with their capabilities for preserving fabrics as well as timber from fire. Should it be decided to impregnate the wood with chemicals, this can be done, or a superficial coating of fireproof and waterproof paint over the wood may be put on, or both; but the Japanese do not paint their wood much, and might not care to do so. In either case it would be necessary to use a preservative, which, in places exposed to rain or washing, would not wash out. How far those non-inflammable salts which unite chemically with the albuminous and nitrogenous matter in the wood are capable of resisting wet it is difficult to say with certainty; but there are some which we shall proceed to give further on which do effectually resist water and soap. Again, it must be a *sine qua non* that, whatever the fireproofing material used may be, it must be one which, when exposed to the action of fire, does not give off injurious or suffocating smoke. Also, if the impregnation of the timber is to be thorough—*i. e.*, through the whole of the wood—it would be most advantageously done whilst the wood is green and the sap uncongealed, otherwise the tubes become clogged, and the injection of the chemicals only extends to a certain depth in the wood if the latter is dry. Impregnating the timber when green, and operating on large balks, would perhaps be more economical than upon smaller pieces when cut up. Moreover, the coarse-grained quickly-grown timber required in this case is most suitable and cheapest; but then salts are said to make wood soft, and cut across the grain, so that it might be difficult with the ordinary handsaw to cut out the more delicate work which is so largely used in Japanese houses. Lastly, if the wood is impregnated while green, the non-inflammable solution acts chemically on the sap and destroys the germs of rot; for although most of the sap is driven out and replaced by the solution, still a little remains in the moist wood, and this would tend to dilute the injected solution, and also cause subsequent decay. Of course, the "shortness" of the wood caused by salts applied to balks, whether prepared when green or well seasoned. These remarks are by way of preface. The following has reference principally to the preservation of telegraph-poles from decay, but is equally

* A paper read before the Civil and Mechanical Engineers' Society.

applicable to our subject. Gavey and Douglas say: "The physical formation of a tree is made up principally of cellular tissue-woody fiber and vascular tissue. Cellular tissue consists of little colorless bladders or vesicles of various figures adhering together in masses and filled with liquids. Woody fiber is an elongated form of cellular tissue incrusted and hardened by various substances, which give the distinguishing characteristics to different classes of timber. Vascular tissue consists of small membranous spiral tubes or vessels which aerate and transmit some of the fluids in the plants. If a transverse section of a piece of exogenous timber be examined, it will be found to consist (1) of a small portion of central pith; (2) the woody portion, divided into the heartwood and sapwood; (3) the bark, which latter is divided into the true bark and epidermis; and, lastly, the medullary rays, which are thin vertical plates connecting the bark and the pith, and radiating from the center to the circumference. In a young shoot, the pith, which consists wholly of cellular tissue, appears to serve as a vehicle for the ascending sap, which, rising from the roots to the leaves, there comes in contact with the air, where it combines with the elements necessary for the formation of the tree. Woody or ligneous fiber and vascular tissue extend vertically downwards, and at the same time cellular tissue is formed horizontally. The ligneous fibers are attached to each other, as it were, in bundles, by their respective coats, whilst the cellular tissue is forced into the thin vertical plates, termed the medullary rays, which connect the pith with the bark (known as silver grain). The residue of the sap descends through the inner bark to the roots; thus a layer of wood is gradually formed between the medullary sheath and the bark, and this continues until the approach of winter and the fall of the leaf stop the operation. On the following spring the sap again ascends, and during the year a second layer of wood is deposited; and as each season advances towards winter the deposit takes place more and more slowly, so that well-defined rings distinguish each year's growth. The number of the rings indicating the age of the tree in years, and the thickness of each ring the rate of its growth. Sometimes in hot climates there is so little difference in activity at various seasons that the rings cannot be accurately defined. In temperate seasons the sap rises during the spring, and leaves are developed. In summer the sap almost ceases to flow, and vegetation remains stationary. In autumn the sap descends, and the leaves fall off. In winter the tree becomes again inactive. In tropical climates the dry season is the period of inactivity. When wood is going to be seasoned in the ordinary way, the best season for felling trees is when the circulation is least active, viz., the middle of the summer or winter periods of quiescence, and during the dry season in tropical climates. After a few years the ligneous fibers deposited nearest the center become darkened, hardened, more dense, and apparently impervious to the sap, which latter circulates upwards through the layers of woody matter last deposited; hence the distinction between the heartwood and the sapwood." Sabine and Douglas say: "Dr. Boucherie has discovered that no connection exists laterally between the tubes of a tree, and that by applying, under a moderate pressure, a colored solution to certain tubes at one end of a tree, the same tubes at the other end of the tree, and only those, are colored. In this way, at one end of a felled tree he applied a colored solution to certain tubes, forming the name 'Faraday;' the name was transmitted to the other end and was perfect at every intermediate section, showing that there was no lateral diffusion." On the other hand, Langdon says, "That there is a lateral connection between the fibers may be proved by reference to a creosoted pole, where, under pressure, the creosote penetrates between one and two inches." It is generally understood that there is some, but very little, lateral connection, so that in order to do it thoroughly the injection should take place from the ends. Inasmuch as the sap in timber contains the elements of decay, in the higher class of construction it is necessary to use wood most free from sap, or to use special means to eliminate it by the internal application of preservative solutions which either expel or neutralize the fermentative portion of the sap. Although the solution used

generally for the preservation of timber from rot need not be the ones best suited for rendering the same fireproof, yet the method of application is similar. We will therefore describe the system most commonly used. It is better and generally cheaper to select soft woods, such as Scotch pine, which is admirably adapted for injecting processes. It is of very coarse grain, its annular rings are wide apart, tissue soft, and capable of great absorption. The idea in the ordinary methods adopted for preserving timber from rot is to introduce into the pores of the wood some salt, which, uniting chemically with the albumen of the sap, is stated to convert it into an insoluble compound. The best known of these processes are Burnettizing, Kyanizing, and Boucherizing (creosote is, of course, out of the question), Burnettizing consists in impregnating the timber with a solution of chloride of zinc, and Kyanizing with corrosive sublimate (chloride of mercury). Langdon says: "In both processes open tanks are filled with the solution with which the timber is required to be charged; the timber is then submerged, well fixed, and allowed to remain soaking until it has absorbed the proper quantity of the solution." Culley says: "Kyanizing, or steeping the timber in a solution of bichloride of mercury or corrosive sublimate, has not been extensively tried for poles because of the expense, and because it does not succeed unless the timber is dry. The poisonous nature of the salt is a very serious objection." Spagnoletti says, with regard to the chloride of mercury process: "Two pounds of corrosive sublimate at 3s. per lb. will be sufficient for 50 cubic feet of timber. The time for preparing should be one day per inch in thickness, and one day over. Thus, two days for one inch, three days for two inches, and so on; one advantage of this preservative is that the timber may be cut down and cast into the tank at once, the sooner the better, and no preparation or seasoning is necessary." He thinks it an excellent preservative of wood. The superficial coating obtained by mere soaking is perhaps good enough for telegraph poles, when the latter are thoroughly dry to begin with, and the heartwood hard; but to make wood fireproof it would be necessary to thoroughly saturate the wood with the solution, and the following mode of injecting telegraph poles is much better. The operation generally takes place in strong cylindrical tanks in which are fitted hemispherical ends, removable at will; to save labor they are usually provided with a line of rails, which communicates with tramways running through the preserving yard. The poles being stacked on light trucks or trollies, are thrust into the tanks, the ends of which being then closed, the interior is exhausted with powerful air-pumps driven by steam. The object of this is to draw out any moisture that may remain in the wood (the timber must be thoroughly dry before it undergoes the operation), and also to create vacuums in the pores, which may be filled by liquid. The liquid is then allowed to flow into the tank, and exposed to pressure varying from 100 to 150 lb. per square inch. The contents of the tanks and the quantity of timber in them being known, the exact quantity of salt injected into the wood per cubic foot can easily be calculated. The salts evidently combine with the elements in the sap which tend most readily to ferment, and by precipitating them and forming new and insoluble compounds check this tendency and lengthen the life of the timber. If a transverse section of a pole thus treated be examined it will be found that the sapwood alone is permeated by the salt, the heartwood remaining untouched. The elements of decay, however, are far more fully developed in the sappy portion of the timber than in the heartwood, and the latter is rarely attacked (speaking of rot, of course, not of fire), until the former is rotten. Sabine says: "The posts are put into wrought-iron cylinders 4½ ft. to 6 ft. diameter, and 34 ft. to 60 ft. long, closed at one end, and covered at the other with tightly-fitting tops. The cylinders are provided with manometers, safety valves, &c., and connected with air and pressure pumps and a reservoir of the preservative solution. The wood is preserved by being subjected to a great pressure of steam, which, penetrating into the interior, not only tends to displace the sap from the pores and prepare them for the preservative solution, but also to coagulate the albumen in the sap and in this way retard the subsequent

rolling. After this the cylinders are exhausted, and immediately filled with a solution of 1 part chloride of zinc and 30 parts of water (for burnettizing), which is kept under a pressure of 8 to 10 atmospheres = 120 to 150 lb. for three hours; but it is questionable if this method is so good as that of Dr. Boucherie (boucherizing), as it is necessary to force the solution into the wood at right angles to the tubes, thereby injuring its strength and letting the sap, which is the immediate cause of decay, remain; the coagulation of the albumen in the sap to any material depth below the surface being a matter of doubt." From this it would appear that the timber need not necessarily be dried prior to the operation, as other men state, and in coarse-grained woods, where the injection is complete throughout the whole bulk. This, then, is the degree of saturation when ordinary strong timber, consisting partly of sap wood and partly of heart wood, even when expensive cylinders with powerful air pumps, &c., are used, so that the following method of injection, which is employed for boucherizing, would (should no after consideration prevent it) be the most suitable for the purpose, should it be wished to completely saturate the woods throughout, since the apparatus is comparatively cheap and portable, the timber best suited being coarse grained, quickly growing, and consequently less costly, and, in fact, of the kind mostly used for house purposes, the operation performed in the forest where the timber is cut down, and whilst it is yet green and full of sap. The method follows: Newly cut green timber (coarse grained is most suitable), before its bark is removed, is exposed at the butt ends to a slight pressure of a liquid column of sulphate of copper: the liquid is usually arranged in tanks at a height of some 50 ft. above the level at which the tree is placed. The pressure forces the liquid through the longitudinal pores of the timber till it drops out at the other extremity, both driving the sap before it and forming the chemical combinations which effect the preservation of the wood from decay. Poles should be exposed to the operation without the slightest delay after they are felled, or the process will probably fail as the resinous substances rapidly harden and prevent the movement of the liquid salt through the pores. The plant needed is inconsiderable, and can be set up in any locality, the only requirement being a clear space of open ground; this gives this system an advantage over others which demand expensive and powerful machinery. The arrangements in a boucherizing yard may be thus described: Any open tank of any convenient capacity is erected on poles at a height varying from 30 ft. to 50 ft. Some prefer 23 ft. to 26 ft. from the ground. Culley says: "24 ft., since, if it is too high, the liquid flows too rapidly through the timber to produce the best effect." From this tank descend two leaden pipes about 1½ in. in diameter, one of which is connected with the force pump designed to fill the tank with liquid, the other serving to convey the liquid to the poles; the latter are laid side by side on racks placed horizontally, and are arranged at right angles to a passage running the whole length of the yard. Down this passage is carried the leaden pipe from the tank, and at regular intervals of 18 in. along this pipe small branch pipes with stopcocks are fitted. As each pole is felled and hauled into the boucherizing space a section is cut off the butt end to expose a fresh uncoagulated surface of wood. Near the circumference of this newly-cut surface a strip or ring of india-rubber is nailed; then a flat board somewhat larger than the base of the pole is screwed again[illegible] by means of iron dogs (tenon bo[illegible] hole in the center of the board [illegible] the insertion of a hollow box[illegible] plug, which is connected with on[illegible] the small branch pipes previously alluded to by means of a short length of flexible india rubber tubing. This plate or disc, together with the india rubber ring just mentioned, forms a watertight chamber for the reception of the solution of sulphate of copper, communicating with the vertical pressure pipe. The air must be carefully expelled from the chamber formed at the butt end of the pole. This is best done by inserting a wire between the pole and the packing, which forms the side of the chamber. After the tap has been turned to admit the solution, the wire is withdrawn, leaving a small hole, and when the liquid spurts out freely, showing that the air has escaped, this hole can be

closed by a blow from a hammer. Neglect of this precaution has frequently prevented the injection of the upper side of the entire pole. The tap being turned, the liquid solution is driven into the pole with a pressure dependent on the height of the tank above the racks. The proportions of the solution are 1 lb. of sulphate of copper to 5 gallons of water (Douglas says 1 part by weight of the salt to 100 parts of water). It is usual to inject 0.35 lb. of the sulphate into every cubic foot of timber. This gives a weight of 1½ to 2 lbs. of sulphate for the smallest pole (about 25 ft. long). After the lapse of a period varying from two to 24 hours, the liquid makes its appearance at the top of the pole and drops into gutters placed conveniently to catch it. Douglas says "three days is the average time required to inject a 25ft. pole." The process is complete when every portion of the top of the pole is found to be saturated with sulphate of copper. This is known to be the case when a brown stain is left on the timber by the application of a piece of potassium ferrocyanide. Another authority says: "Scotch fir having a very open grain is the best suited for preservation by injecting process. To boucherize successfully, the worst timber (that is, as regards its chance of lasting unprepared) is wanted. In some cases, where the poles were too old, a month elapsed before the copper liquid applied to the butt appeared at the top of the poles." Another authority of large experience says: "Scotch fir, grown on a peaty soil, coarse grain and open. The average time taken to successfully boucherize three 28ft. poles, during the months of April, May, June, July, August and September, was from five to seven days. In October, November, and December, January, February and March, about ten days. In June, the quantity of liquid that percolated through three 28ft. poles was 68 gallons; and soft larch took a few days longer than the Scotch, but answered very well. Some few red or hard larch were successfully done, but in others the solution only penetrated a very short way from the end. Spruce and silver pine answer well, but take much longer than do either larch or Scotch." Cully says: "It is quite possible to inject trees that have been cut down two or three weeks; but the labor will be much more costly than when injected in the forest on the day they are felled, because the pores contract in drying. It is extremely difficult to inject larch unless it is of very open grain and very free from resin. The liquids cannot penetrate the hard wood, and it has sometimes happened in boucherized poles that the heart wood, which is more durable than the sap wood under ordinary circumstances, has rotted, leaving the sap wood sound. Spruce and Scotch fir are very suitable, and these cheaper descriptions of fir are rendered more durable than the more expensive sorts when unprepared. The cost of the sulphate process calculated on 5,287 Scotch fir-poles injected in the forest, and averaging 25 ft. in length, is about 2d., equal to 4 cents, per lineal foot of timber." Another authority says: "The process is most successful during the spring and summer months (Culley says the autumn), when the sap is in the wood. Cold hinders, and frost stops it." Timber, when chosen for strength and seasoned in the ordinary way, is, of course, felled in the winter months, when the sap has retreated from the wood. It is possible to treat the wood, with equal success, from the top or small end as from the butt end. The application of the sulphate of copper to the small end instantly starts the sap, which pours out from the large end. The boucherizing of the pole was completed, in a particular experiment, in the usual time. In the construction of a house it would be necessary, in the case of the upright timbers which stand in the moist ground, to provide for the escape of the fireproof salt by painting the lower end with a coating of some soluble or waterproof paint, which should also be fireproof. Such a paint we shall give further on. Without this precaution much of the salt is lost in the ground, and the surrounding ground in which the boucherized pole stands will be found tainted for some 12 in. or more with sulphate of copper." Mr. Boucherie says, however: "It is an error to suppose that the sulphate of copper is very soluble, or that when it is exposed to the rain its preservative power disappears after a certain time. The sulphate of copper fixes itself into the elements of the wood, and

could not be dissolved by washing. Cases of failure are to be attributed to a disease in the wood, the diseased tissues seeming to resist the sulphate." Professor Abel also objects to the theory of the salt being washed out when a telegraph pole is standing in moist ground. He says: "I believe a small quantity of the copper salt is converted into insoluble compound. The action of the metallic compounds is to combine with certain albuminous substances in the wood, by which they are converted into insoluble substances, and it is by the chemical alterations which these undergo that the preservative effect is produced." It is generally allowed, however, that the preservative effect of sulphate of copper is very variable. Professor Abel, judging from experiments on boucherizing and kyanizing for the preservation of wood from decay, says: "Generally the results were favorable to boucherizing." He believes, "Opinions are fairly divided between them—that is, the copper salts and mercury salts, which are undoubtedly both good preservative processes." Mr. Boucherie says: "Sulphate of copper combines so well with the celluline that washing with pure water will never expel it." Culley says: "The sulphate of copper must be free from iron as it is inert and possibly hurtful; besides this, the iron becomes oxidized by exposure to the air and forms a muddy deposit, which chokes the fine filter formed by the pores at the end of the pole and thus stops the process, as the sulphate always contains *some* iron (Japanese sulphate of copper obtained from the Mint contains a large quantity, but varies much in this respect). It is well to make a saturated solution, and allow it to remain exposed to the air as long as possible, so that the iron may deposit at the bottom of the vessel, after which it may be diluted for use. If the solution is too strong, it appears to contract the sap vessels and to crystallize at their ends. The water must be free from lime and perfectly clear. If it contains lime it is as well to add a little sulphuric acid to precipitate it, and either allow it to settle or filter the water through sand, for even the slightest cloudiness interferes with the injection.

"All timber, when treated by any of the preservative processes in general use, becomes short; that is, it breaks in two, crosswise, easily, and when the whole wood is impregnated its tensile strength becomes impaired. It no longer, when dry, retains the same amount of elasticity it possessed when in its natural state; when in a moist state it recovers a great deal of this. The shortness is easily tested by taking a piece of dry, preserved timber and trying to split it with an axe, it will be found that the axe will not follow the course of the grain of the wood." This, then, seems a reason in favor of impregnating the wood, and especially the smaller pieces, after they have been cut to fit into their several places. Again Sabine says: "It is necessary that no ungalvanized iron should come in contact with wood impregnated with sulphate of copper (and the same point must be considered when using other salts, otherwise the copper of the solution will be reduced by galvanic action)." Another authority says: "Boucherizing is injurious to the stay wires and bolts, as the sulphur so quickly attacks not only the galvanizing of these, but the iron itself, that the stay wires of poles are soon eaten away." This shows that when salts are used for impregnating wood, iron bolts and nails should be protected in some way—by paint, say. Kyanizing (chloride of mercury) is equally injurious to iron. Another process for preserving wood from decay is Beer's process, in which *borax* is used. It is supposed to neutralize the decaying vegetable matter in the wood, and is also a very good non-inflammable solution. We have entered thus fully into the methods of preparing wood with sulphate of zinc, chloride of mercury, and sulphate of copper in particular, because whatever may be the non-inflammable solution selected as most suitable, some such method of injection will be necessary if the impregnation is required to be other than merely superficial, in which case the same considerations would apply. Moreover, since all the three above-mentioned are salts, they will not only preserve the wood against rot, the influence of the weather, insects and worms, but will render it also to a certain degree non-inflammable, but which non-inflammable solution is best we shall probably be better able to judge further on. But we should, to begin

with, put chloride of mercury and sulphate of copper out of the question, as the first is too expensive, and when burnt is turned into vapor which has a fearfully suffocating effect on the nose. Sulphate of copper, though cheap and free from this disadvantage, would turn the wood a blue color when the surface is damp with the moisture in the air. Chloride of zinc and borax, the other two of the above-mentioned processes, both preserve from decay and flame, and might be used for injecting green timber. But, at present, let us go through the information that can be gathered on the subject of non-inflammable compounds and solutions. Much of this relates to rendering fabrics non-inflammable, and this is done by steeping them in almost any saline solution. Thus, cotton and linen stuffs prepared with a solution of borax, phosphate of soda, phosphate of ammonia, alum, or sal-ammoniac, do not suffer active combustion nor burst into flame. The salts act by forming a crust of incombustible matter on the surface of the fibers. They do not, however, prevent carbonization taking place when the temperature is sufficiently high. The cotton thread is reduced to a cinder when burnt, but from the action of the salt its fibers still retain sufficient tenacity to support a light weight. The addition of 1 oz. of alum or sal-ammoniac to the last water used to rinse a lady's dress, or a less quantity added to the starch to stiffen them, renders them non- inflammable, or, rather, they will not readily take fire, and, if kindled, are slowly consumed without flame. None of the above are used for fine, soft muslins, because they render the fabric harsh, and destroy all its beauty. The salt which is found to answer all conditions most completely is tungstate of soda; steeped in a solution of 20 per cent. of this salt, muslin is perfectly non-inflammable when dry, and the saline film left on the surface is of a smooth and fatty appearance like tallow, and does not interfere with the process of ironing. The non-fulfillment of this last condition completely prevents the use of many other salts, such as sulphate or phosphate of ammonia, which are otherwise efficacious in destroying their inflammability. The addition of a little phosphoric acid, or phosphate of soda, is recommended to the tungstate, for without this a portion of the tungstate is apt to undergo a chemical change, and become comparatively insoluble. For a solution of tungstate of soda of minimum strength, dilute a concentrated solution of neutral tungstate of soda to specific gravity, 1.14, and then add 3 per cent. of phosphate of soda. This solution is found to keep, and answer its purpose well. Again, in Ure's Dictionary, "Cotton and linen cloth may be best rendered incapable of burning with flame by being imbued with a solution of sal-ammoniac or of alum." Tomlinson says: "Experiments were tried with 40 salts, but out of these only four appear to be applicable to light fabrics—namely, phosphate of ammonia, chloride of ammonium (sal-ammoniac), sulphate of ammonia, and tungstate of soda. The sulphate of ammonia is the cheapest salts, but causes brown spots on the muslin when ironed, and dissolves in water, so that it requires to be renewed after every washing. Tungstate of soda is the only one that does not interfere with the iron, and consequently is that usually adopted. The oxides of tin withstand both the water and the soap, but they impart a yellow tinge, consequently their application has been restricted to canvas, sails, and other coarse materials (and would not affect their use with woods). This is also the case with borate and phosphate of protoxide of tin and arseniate of tin. These last are some of the attempts which have been made to fix some of the non-soluble compounds in textile fabrics. The method of rendering a sailcloth permanently non-inflammable is to so soak the canvass for two days in a protochloride of tin solution of the strength of two parts of the salt to one of water, and to leave it for a day in a concentrated solution of stannate of soda or carbonate of soda. The canvas is lastly dried, and is then ready for use." Also, we find in the "English Cyclopædia": "Cotton and linen fabrics may be partially protected from fire by a solution of alum or common salt; but alum weakens the fibers, and the salt makes them harsh and crisp; borax will exert a considerable preservative effect, but the material is weakened, as with alum. It was found that phosphate of ammonia exerts the preservative effect; but the salt becomes decomposed under the laundress's iron.

Sulphate of ammonia (only quarter the price of its predecessor) had most of its merits, but the same defect. Tungstate of soda has all the advantages, and is free from the disadvantages." So much for fabrics. Of course, what would be a disadvantage for linens need not be so for woods; but I give the above as an addition to our list of non-inflammable solutions, to guide us to the selections of the most suitable ones hereafter. The "English Cyclopædia" says, with regard to wood: "Many methods have been devised for making woods more or less fireproof. The substance which is attracting most notice now is silicate of soda. Mr. Abel, chemist to the War Department of England, and Mr. Hay, chemist to the English Admiralty, made experiments on this salt in 1857. A portion of a wooden hut was painted three times, inside and out, with a solution of silicate of soda; but unfortunately for the fairness of the experiment, the building was constructed with a double boarding, so that it was only possible to coat or impregnate each plank on one side; but the value of the silicate was established beyond a doubt. A flame from a large heap of shavings was placed against this part of the building for some minutes, but only succeeded in catching the end of one plank, and even that did not blaze, but only smouldered for a short time. By the heat of the fire the salt was drawn to the surface of the wood, and formed a glaze upon it. Subsequently, when the main body of the hut was destroyed by fire, after several unsuccessful attempts to extinguish it by Phillip's Fire Annihilator (for testing the efficiency of which the experiment was made, the silicate of soda experiment being only a secondary one), although the fierceness of the flame was such that few materials could have withstood it, yet several planks remained of the exterior coated portion. Upon examining the planks, the unprotected surfaces were found to be completely charred, but this charring only extended to those parts which had not been touched by the silicate. Asbestos paint has been used with nearly similar results. So far as experiment has gone, silicate of soda appears the most convenient and effective known for the purpose." Again, respecting silicate of soda, "Spon's Workshop Receipts" says: "Deal boards become almost incombustible when painted over with a diluted solution of silicate of soda called also glass water. The glass water is generally sold as a thick fluid like honey. This may be thinned out with water six or seven times its own bulk; the water must be soft, or boiled water will do, and apply the solution warm. In about 24 hours apply a second coat, and, perhaps, a third. Use a new brush, and wash the brush in clean water after using, or it will get too soft. Avoid grease or fat on the boards before painting them." In the same book is another receipt, as follows: "Soak the wood in a strong solution of alum and sulphate of copper—about 1 lb. alum and 1 lb. sulphate of copper should be sufficient for 100 gallons of water. These substances are dissolved in a small quantity of hot water, then mixed with the water in the vessel in which the wood is to be steeped. The timber to be rendered fireproof can be kept under the liquor by stones, or any other method of sinking it. All that is required is a watertight vessel of sufficient dimensions to hold enough of the liquor to cover the timber, which should be allowed to steep for four or five days; after this it is taken out and allowed to dry thoroughly before being used." This would be a very good plan to adopt with the upright timbers after thoroughly injecting them by the system of boucherizing, as before explained, whilst the timber is green. As the Japanese use their wood plain, the blue sulphate of copper tinge would hardly do for the lighter woodwork. With regard to burnettizing, sulphate of zinc, which, as before mentioned, has been largely used as a preservative against decay, there is no reason why it should not be used for every part of the wood in a house, injecting it whilst the wood is green, as it acts chemically on the sap, and is white. Sir W. Burnett says of it that it renders the wood non-inflammable. The following is extracted from his pamphlet on the subject: "For preserving timber, canvas, cordage, and woolen things from dry rot, mildew, moth, and the destructive influences of the elements, salt water, so far from hastening decay or neutralizing its effects, has, on the contrary, the quality of increasing its efficacy; it is

perfectly innocuous, and cannot endanger health. All the timber and ceilings of a ship may be impregnated with the solution without the slightest prejudicial effect on the crowded inmates. It retards the oxidization of metals, as has been proved repeatedly upon copper and iron bolts, with the most satisfactory results, and articles prepared with this solution will resist combustion in proportion to the strength of the solution used." Again, another method: "In Maughan's process, dry wood is saturated with an aqueous solution of phosphate of soda and muriate or sulphate of ammonia. A decomposition ensues, followed by an evolution of ammoniacal vapor, and the formation of an incombustible coating on the surface of the wood." Jackson's patent consists in the application of a solution of salts of zinc and ammonia. Mr. Payne's wood-preserving process is well known. Wood is rendered fireproof by means of a solution of sulphuret of barium or calcium. The wood or other vegetable matter is put into an air-tight vessel, from which the air is driven out by means of steam. The steam is condensed by the injection of the solution of the sulphuret, and by the application of cold water to the outside of the vessel. A partial vacuum being thus obtained, the solution is allowed to flow into the vessel from the tank containing it through a pipe furnished with a stopcock. The stopcock is then closed, and an air-pump connected with the vessel is worked until as perfect a vacuum as possible is obtained within the vessel. The cock is then again opened to allow the solution to fill the vessel nearly. It is then shut, and by means of a force pump a further quantity of solution is introduced, until the pressure on the interior of the vessel amounts to 110 lbs. to 140 lbs. per square inch. This pressure is maintained for an hour, and the solution is then drawn off. The vegetable matter is then impregnated in a similar manner with an acid or a solution of some substance, such as sulphate of iron, which will unite with the barium or calcium, and set the sulphur free. When the vegetable matter is to be impregnated with a large quantity of solid matter it should be dried between the application of the two fluids. By this means an insoluble sulphate of lime or sulphate of barium is formed in the body of the wood, which is thus rendered nearly as hard as stone. Wood so prepared is now largely employed in English public works and railways. Of this same process Payne himself says: "By impregnating wood with a solution of metallic oxides, alkalies, and earths in various proportions, using exhaustion and pressure to do it, and then in order to prevent the disunion of such solutions by introducing another solution by a similar means, an insoluble substance is formed in the interstices of the woods. Wood subjected to this process is not only proof against wet and dry rot in every situation, but will not communicate flame, and will resist the attacks of insects. The most porous, the softest, and, of course, the cheapest woods are rendered equal in point of usefulness, durability and strength to the hardest and best description of timber. Wood thus prepared is susceptible of the finest polish. As a preventative to the spread of flame, especially in countries where the houses are for the most part composed entirely of wood, and in most cases covered with wood shingles—the use of this process will be of the utmost importance, and will greatly lessen, if not entirely prevent, the dreadful catastrophe so frequently occurring there from fire. For all outdoor work, to whatever inclemency of the weather it may be exposed, the advantages are great, and also for sleepers and other works on railways, as also for wood pavement. For canvas and cordage, by the proper application of this process, all the advantages named are communicated without injury to their elasticity. Sails, rigging of ships, canvas for tents, tarpaulings, &c., are by this means effectively protected and improved." Again, "Herbert's Encyclopædia" says: "Many ingenious experiments have been resorted to to render wood fireproof. Solutions of muriate of ammonia, muriate of soda, sal ammoniac, borax, alum, and several other salts and alkalies have this property to a certain extent. Professor Fuchs invented a solution for this purpose—10 parts potassa, or soda; 15 parts of pure silicious earth, and 1 part charcoal mixed with water. This composition, applied to the surface of the wood, forms a vitreous coat, which

effectually resists the action of fire. Decisive experiments fully established the efficacy of this plan, and the Royal Theater of Munich was protected by the application of this composition. The surface covered was upwards of 400,000 square feet, and the expense, it is said did not exceed 5,000 francs—£200, or less than 4s. for 400 square feet. The following is an English composition for a like purpose: 1 part, by measure, of fine sand, 2 parts of wood ashes, and 3 parts slaked lime ground together with oil, and laid on with a painter's brush; the first coat thin, and the second thick. This forms a very strong and adhesive compound, which is both fireproof and waterproof. Again, Solomon's patent consists in a peculiar application of two solutions to the surface of the wood, the first consisting of sulphate of alumina, glue and water, and the second of chloride of calcium, glue and water." Also, in "Spon's Workshop Receipts": "A wash composed of lime, salt, and fine sand, or wood ashes, put on in the ordinary way of whitewash, renders a shingle roof fifty-fold more safe from fire from falling cinders in case of fire in the vicinity. It has also a preserving influence against the effect of the weather. The older and more weather-beaten the shingles the more benefit derived. Such shingles are generally more or less warped, rough and cracked. The application of the wash by washing the upper surface restores them to their original or firm form, thereby closing the space between the shingles and the lime and sand; filling up the cracks prevents it from warping. By the addition of a little lampblack, the wash may be made of the same color as old shingles, and thus remove the offensive glare of a whitewashed roof." Such is the information we are able to glean, so far; and before offering any suggestion of our own as to the best mode of proceeding, let us remember that to season timber in the ordinary way requires seldom less than three years', often six or eight years' exposure to the air freely; and though (owing to the suffocating fumes emitted when exposed to great heat) Kyan's (chloride of mercury) is out of the question for us, still the burnettizing (chloride of zinc), boucherizing (sulphate of copper), and beerizing (borax) systems the destructive principle (sap) is dried and rendered inert. They render larch, firs of all kinds, willow, birch, elm, beach, ash, poplar, &c., of considerable value for durable purposes. We would, therefore, suggest for houses already built: Apply several washings of silicate of soda to the fixtures of every description, and let the removable lighter work, roof shingle (when used), mats, &c., soak several days in the same solution. Where shingle roofs are used, let these be afterwards coated with lime, salt, fine sand, or wood ashes. When new houses are to be built, impregnate the main or thick timbers thoroughly with chloride of zinc by pressure, obtained as in boucherizing, whilst the timber is green; allow it to dry thoroughly before fixing, and paint the outside with silicate of soda three times when in position. The lighter woodwork, shingles, &c., can be cut from large balks thus impregnated, and afterwards washed superficially with silicate of soda, or this thin woodwork may be saturated by steeping in silicate of soda for several days. By the use of the above comparatively simple and inexpensive remedies, all complicated steam-pressure paraphernalia, vacuum pumps, &c., are avoided. The area of fires would be greatly reduced, whilst a scheme of fire assurance would become feasible where these precautions were taken by the inhabitants of any block of buildings, as any spread of a conflagration would be arrested and kept in check at such a small loss to the outside houses of the block, as would fall lightly on any company holding an assurance on the whole block. The inhabitants of any block of houses might assure against fire amongst themselves, on condition that the above precautions were observed by all, whilst any jealousy on account of vested interests of firemen might be met by paying a certain sum, to be approved by former statistical returns, to fire brigades, and deducting according to the number and extent of fires, not to pit any district fire brigade against another for a prize, as that would only lead to a prevalence of fires (accidental, of course) in opposing districts.

THE Columbo breakwater is finished, and the Ceylon *Observer* advocates the construction of a northern arm to the breakwater and docks.

ABSTRACT OF RESULTS OF EXPERIMENTS ON RIVETED JOINTS, WITH THEIR APPLICATION TO PRACTICAL WORK.*

By Prof. ALEXANDER B. W. KENNEDY.

From "The Engineer."

The experiments, of which the following is an abstract, consist of fourteen series, and cover in all 290 experiments, 64 on perforated—punched and drilled—plates, 97 on actual joints, 44 on the tenacity of the plates used in the joints, 33 on the tenacity and shearing resistance of the rivet steel used in the joints, and the rest on various other matters connected with them. All the joints in the whole series were supposed to be made of the same material, a soft steel or ingot iron, supplied from the Landore-Siemens Steel Works; and that all the rivets were made from rivet steel supplied from the same works.

Having summarized the experiments themselves, the author proceeds to summarize the conclusions which it appears safe to draw from them, to examine the proportions of joint which they appear to indicate as the best, and to mention the points on which further information is now being obtained. In accordance with the plan pursued in the rest of this abstract, this will be done in the briefest possible manner, without discussing the points at length as they occur. In most cases a much more detailed treatment of them will be found in the various reports of the riveting committee, of which this is only an abstract. It will be remembered, and may be again stated here once for all, to avoid repetition, that the conclusions given below all refer to joints made in soft steel plate with steel rivets, that the holes were all drilled, and that the plates were in their natural state—unannealed. Further, it should be said, that all dimensions, thicknesses of plate, &c., were measured by the most accurate means available; and in every case the rivet or shearing area has been assumed to be that of the holes, not the nominal—or real—area of the rivets themselves. Also in every case the strength of the metal in the joint has been compared with that of strips cut from the same plates, and not merely with nominally similar material. It is thought that, if these points had always been attended to, many of the discrepancies in published riveted-joint experiments would never have appeared.

(1). The metal between the rivet holes has a considerably greater tensile resistance per square inch than the unperforated metal. This excess tenacity amounted to more than 20 per cent.—both in $\frac{3}{8}$ inch and $\frac{3}{4}$ inch plates—when the pitch of the rivet was about 1.9 diameter. In other cases $\frac{3}{8}$ inch plate gave an excess of 15 per cent. at fracture with a pitch of 2 diameters, of 10 per cent. with a pitch of 3.6 diameters, and of 6.6 per cent. with a pitch of 3.9 diameters; and $\frac{3}{4}$ inch plate gave 7.8 per cent. excess with a pitch of 2.8 diameters.

(2). The shearing resistance of the rivet steel is a matter upon which, as has been pointed out, further experiment is required. It may be taken as established that the resistance per square inch in double shear is as great as that in single shear, so that allowance need not be made for the two shearing planes not being equally stressed. In single-riveted joints, however, the bending of the plates will put considerable tensile stress in the rivets; and this may diminish their apparent shearing resistance. In single-riveted joints it may be taken that about 22 tons per square inch is the shearing resistance of rivet steel,* when the pressure on the rivets does not exceed about 40 tons per square inch. In double-riveted joints, with rivets of about $\frac{3}{4}$ inch diameter, most of the experiments gave about 24 tons per square inch as the shearing resistance, but the joints in Series XIII. went at 22 tons. In Series XIII. the larger rivets also went at a low load; but in the other double-riveted joints, with larger rivets, these latter remained unbroken at a stress of 22 tons per square inch.

* Abstract of paper read before the Institution of Mechanical Engineers.

* In one pair of single-riveted joints only a shearing resistance of over 24 tons per square inch was reached; in none of the other did it exceed 22.5 tons.

(3) The size of the rivet heads and ends plays a most important part in the strength of the joints—at any rate in the case of single-riveted joints. An increase of about one-third in the weight of the rivets—all this increase, of course, going to the heads and ends—was found to add about 8½ per cent, to the resistance of the joint, the rivets remaining unbroken at twenty-two tons per square inch instead of shearing at a little over twenty tons.* The additional strength is, no doubt, due to the prevention of so great tensile stress in the rivets through distortion of the plates.

(4) The strength of a joint made across a plate is equal to that of one made in the usual direction. (Both this conclusion and the last preceding are stated as the result of a very limited number of experiments; but there seems no reason to doubt their general truth.)

(5) The intensity of bearing pressure on the rivets exercises, with joints proportioned in the ordinary way, a very important influence on their strength. So long as it does not much exceed 40 tons per square inch—measured on the projected area of the rivets—it does not seem to affect their strength; but pressures of 50 to 55 tons per square inch seem to cause the rivets to shear in most cases at stresses varying from 16 to 18 tons per square inch. This conclusion is based on the experiments of Series X., in which the margin was made equal to the diameter of the drilled hole. For ordinary joints, which are to be made equally strong in plate and in rivets, the bearing pressure should, therefore, probably not exceed 42 or 43 tons per square inch. For double-riveted butt joints, perhaps, as will be noted later, a larger pressure may be allowed, as the shearing stress may probably not exceed 16 or 18 tons per square inch when the plate tears. But in this case it would probably be wise to increase the margin.

(6) A margin—or net distance from outside of holes to edge of plate—equal to the diameter of the drilled hole, has been found sufficient in all cases hitherto tried.

(7) To attain the maximum strength of a joint, the breadth of lap must be such as to prevent it from breaking zigzag. Such a method of fracture must inevitably be accompanied by unequal stresses in the plate straight between the rivet holes, and by consequent diminution of strength. It has been found that the net metal measured zigzag should be from 30 to 35 per cent. in excess of that measured straight across, in order to insure a straight fracture. This corresponds to a diagonal pitch of $\frac{2}{3}p+\frac{d}{3}$, if p be the straight pitch and d the diameter of the rivet hole. To find the proper breadth of lap for a double-riveted joint, it is probably best to proceed by first setting this pitch off, and then finding from it the longitudinal pitch or distance between the centers of the lines of rivets.

(8) Visible slip or "give" occurs always in a riveted joint at a point very much below its breaking load, and by no means proportional to that load. A careful collation of all the results obtained in measuring the slip indicates pretty clearly that it depends upon the number and size of the rivets in the joint, rather than anything else, and that it is tolerably constant for a given size of rivet in a given type of joint. The loads per rivet at which a joint will commence to slip visibly are approximately as follows:

Rivet diameter.	Type of joint.	Riveting.	Slipping load per rivet.
¾ inch	Single riveted	Hand	2.5 tons
"	Double riveted	"	3.0 to 3.5 tons
"	"	Machine	7 tons
1 inch	Single riveted	Hand	3.2 tons
"	Double riveted	"	4.3 tons
"	"	Machine	8 to 10 tons

To find the probable load at which a joint of any breadth will commence to slip, it is only necessary to multiply the number of rivets in the given breadth by the proper figure taken from the last column of the table above. It will be understood that the above figures are not given as exact; but they represent very well the results of the experiments in all series from VIII. to XIII., except Series X., in which the average—for 1 inch rivets—was much lower than that given above. In this series, however, the proportions of the joints were intentionally somewhat abnormal; and it is, perhaps,

* See "Proceedings," 1881, pp. 713, 714.

not to be expected that in this respect their results should agree with those of the other experiments. This result as to the slipping of a joint, although, perhaps, unexpected, is not contrary to what ought to have been expected. For experiments show that, long before stresses are reached which could visibly stretch the plates of a joint, there will be quite measurable shear of the rivet. The visible slip, therefore, will consist almost wholly of this shear, the magnitude of which will depend primarily on the number and size of the rivets in the joint. Anything that will hold the plates up better together, such as hydraulic pressure on the rivets, might be expected to diminish this shear or delay its commencement—exactly as seems to have happened. The following table gives the results of experiments on this matter which were made along with those given in the Committee's first Report, but which have not been previously published in the "Proceedings" of the Institution. The experiments are on 1 inch turned pins of rivet steel, tested in the single-shear apparatus already described. Of course, the shear would commence later, and be at first smaller in extent, when the pin was replaced by an actual rivet, and when the plates were thus forcibly held together, instead of being quite free to slide, except as far as held from motion by the resistance to shear.

(9) The value of machine-riveting, as compared with hand-riveting, in cases where sound hand-riveting is possible, lies mainly, if not entirely, in the fact that it doubles the load at which the slip of a joint commences. This conclusion is subject to modification by future experiments with the use of higher pressures in closing the rivet, which may probably still further raise the slipping load, so that the advantage of machine-riveting may quite possibly be even greater than it is here assumed to be; but there is no indication that it is likely to affect the ultimate strength of the joint. The question of *friction* in the joint, which has not been specially experimented on by the committee, no doubt comes in in the same way. The friction induced by the rivet will affect the point at which slip commences, but can hardly have much, if any, relation to the breaking load. It is thought that the load at which visible slip commences is probably proportional to the load at which leakage would begin in a boiler. Looked at this way, it will be seen that the great value of hydraulic riveting appears to lie rather in the increased security and stiffness it gives at ordinary working loads than in any actual raising of the breaking load. From a practical point of view the former is probably the more, and not the less, important function. Further experiments are now in

Shearing Stress in lbs. per square inch.	Test Numbers. 343	344	345	346	347	348
	Amount of Shear in Inches.					
0	0.0	0.0	0.0	0.0	0.0	0.0
6,365	.010	.013	.016	.022	.055	.021
12,730	.022	.028	.030	.034	.066	.032
19,100	.034	.040	.042	.048	.078	.043
25,460	.055	.060	.060	.071	.091	.062
28,320	.066	—	—	—	—	—
31,830	.080	.086	.082	.091	.113	.183
35,010	.093	—	—	—	—	—
38,190	.113	.113	.108	.114	.140	.108
41,380	.141	—	—	—	—	—
44,550	.168	.152	.142	.170	.171	.155
47,740	.200	—	—	—	—	—
50,910	.242	.200	.196	.248	.238	.222
54,110	—	—	—	—	—	—
Breaking load { lbs...	54,110	54,930	55,240	52,830	56,670	53,530
per sq. inch { tons...	24.15	24.52	24.66	23.59	25.29	23.90

progress to test the effect of higher closing pressures on the rivet than were used in Series XII. and XIII., the results of which, it is hoped, will allow more definite conclusions to be arrived at in respect to the comparative merits of hydraulic and hand riveting.

(10) The experiments point to very simple rules for the proportioning of joints of maximum strength, which will be mentioned before any other joints are discussed. Assuming that a bearing pressure of 43 tons per square inch may be allowed on the rivet, and that the excess tenacity of the plate is 10 per cent. of its original strength,* the following short table gives the values of the ratios of diameter d of the hole to thickness t of plate $\left(\frac{d}{t}\right)$ and of pitch p to diameter of hole $\left(\frac{p}{d}\right)$, in joints of maximum strength in $\frac{3}{8}$ inch plate:

Original Tenacity of Plate. Tons per Sq. Inch.	Shearing Resistance of Rivets. Tons per Sq. Inch.	Ratio $\frac{d}{t}$	Ratio $\frac{p}{d}$	Ratio Plate area / Rivet area
30	22	2.48	2.30	0.667
28	22	2.48	2.40	0.785
30	24	2.28	2.27	0.713
28	24	2.28	2.36	0.690

Summed up and rounded off, this means that the diameter of the hole—not the diameter of the rivet cold—should be two and a-third times the thickness of the plate, and the pitch of the rivets two and three-eighth times the diameter of the holes.† In mean also it makes the plate area 71 per cent. of the rivet area. If a smaller rivet be used than that here specified, the joint will not be of uniform and therefore not of maximum strength; but with any other size of rivet the best result will be got by use of the pitch obtained from the formula formerly cited,

$$p=a\frac{d^2}{t}+d$$

where, as before, d is the diameter of the hole. The value of the constant a in this equation is as follows:

For 30-ton plate and 22-ton rivets, $a=0.524$
" 28 " 22 " 0.558
" 30 " 24 " 0.570
" 28 " 24 " 0.606

or in the mean, the pitch $p=0.56\frac{d^2}{t}+d$.

It should be noticed that with too small rivets this gives pitches often considerably smaller in proportion than $2\frac{3}{8}$th times the diameter. For double-riveted lap joints a similar calculation to that given above, but with a somewhat smaller allowance for excess tenacity on account of the large distance between the rivet-holes, shows that for joints of maximum strength the ratio of diameter to thickness should remain precisely as in single-riveted joints; while the ratio of pitch to diameter of hole should be 3.64 for 30-ton plates, and 22 or 24-ton rivets, and 3.82 for 28-ton plates with the same rivets. Here, still more than in the former case, it is likely that the prescribed size of rivet may often be inconveniently large. In this case the diameter of rivet should be taken as large as possible; and the strongest point for a given thickness of plate and diameter of hole can then be obtained by using the pitch given by the equation

$$p=a\frac{d^2}{t}+d,$$

where the values of the constant a for different strengths of plate and rivet may be taken as follows: [See table next page.]

Practically we may say that, having assumed the rivet diameter as large as possible, we can fix the pitch as follows, for any thickness of plate from $\frac{3}{8}$ in. to $\frac{3}{4}$ in.:—

For 30-ton plate and 24-ton rivets
" 28 " 22 "
$$p=1.16\frac{d^2}{t}+d$$

For 30-ton plate and 22-ton rivets
$$p=1.06\frac{d^2}{t}+d$$

For 28-ton plate and 24-ton rivets
$$p=1.24\frac{d^2}{t}+d$$

* The excess strength is taken lower than the average result of the experiments, because it is probable enough that the steel used had more than the average softness.

† The small difference here from the constants formerly given is due to the assumption, now quite justified, of a somewhat greater bearing pressure than was then allowed.

Table of Proportion of Double-riveted Lap Joints, in which

$$p = a\frac{d^2}{t} + d.$$

Thickness of Plate.	Original Tenacity of Plate. Tons per Sq. Inch.	Shearing Resistance of Rivets. Tons per Square Inch.	Value of constant a.
$\frac{5}{8}$-inch	30	24	1.15
"	28	24	1.22
"	30	22	1.05
"	28	22	1.12
$\frac{3}{4}$-inch	30	24	1.17
"	28	24	1.25
"	30	22	1.07
"	28	22	1.14

In double-riveted butt joints it is impossible to develope the full shearing resistance of the joint without getting excessive bearing pressure, because the shearing area is doubled without increasing the area on which the pressure acts. In the writer's last report it was shown that, considering only the plate resistance and the bearing pressure, and taking this latter as 45 tons per square inch, the best pitch would be about four times the diameter of the hole. It appears justifiable, however, to apply here the results of Series X., and take corresponding constants. Thus we may probably say with some certainty that a pressure of from 45 to 50 tons per square inch on the rivets will cause shearing to take place at from 16 to 18 tons per square inch. Working out the equations as before, but allowing excess strength of only 5 per cent. on account of the large pitch, we find that the proportions of double-riveted butt joints of maximum strength under given conditions are those of the following table:

Original Tenacity of Plate. Tons per Sq. Inch.	Shearing Resistance of Rivets. Tons per Sq. Inch.	Bearing Pressure. Tons per Sq. Inch.	Ratio $\frac{d}{t}$	Ratio $\frac{p}{d}$
30	16	45	1.80	3.85
28	16	45	1.80	4.06
30	18	48	1.70	4.03
28	18	48	1.70	4.27
30	16	50	2.00	4 20
28	16	50	2.00	4 42

Practically, therefore, it may be said that we get a double-riveted butt joint of maximum strength by making the diameter of hole about 1.8 times the thickness of the plate, and making the pitch 4.1 times the diameter of the hole. These are very nearly the proportions which were used for the $\frac{5}{8}$ inch joints in Series XI. to XIII.; for the $\frac{3}{4}$ inch joints the diameter of the rivet was, as with the lap joint, less than that indicated by theory. In thick plates, where it is thought impossible or inconvenient to make the rivet-holes so large as 1.8 times the thickness, the best pitch for any assumed diameter of rivet cannot be found by the method formerly used; for here we have not a given maximum shearing stress to work to, but rather the shearing stress which in a given joint causes a given maximum pressure on the rivets. The best ratio of pitch to diameter of hole in double-riveted butt joints of maximum strength for any assumed diameter of hole, d, is, therefore, the same as that given in the last table, or in mean, 4.1.

(11). All the experiments hitherto made have necessarily connected themselves with the question of strength, and the proportions just given belong to joints of maximum strength. But in a boiler the one part of the joint, the plate, is much more affected by time than the other part, the rivets. It is therefore not unreasonable to estimate the percentage by which the plates might be weakened by corrosion, &c., before the boiler would be unfit for use at its proper steam pressure, and to add correspondingly to the plate area Probably the best thing to do in this case is to proportion the joint not for the actual thickness of plate, but for a nominal thickness less than the actual by the assumed percentage. In this case the joint will be approximately one of uniform strength by the time it has reached its final workable condition; up to which time the joint as a whole will not really have been weakened, the corrosion only gradually bringing the strength of the plates down to that of the rivets. Thus, suppose a single-riveted lap joint in $\frac{5}{8}$ inch plate is in question, and it is considered that corrosion will make this equal to only $\frac{1}{2}$-inch plate before the boiler pressure has to be lowered The rivet should then be proportioned as if the plate had a thickness of 0.5 inch, which

would give for 30-ton plate and 22-ton rivets (see Table, preceding page) a diameter of hole of 1.24 inch. Assume this as too large to be convenient, and take the diameter of hole as 1 inch. Then from the Table, preceding page, the pitch will be

$$p=\frac{0.524}{0.5}+1=2.05 \text{ inches.}$$

The ratio of plate to rivet area to start with will be 0.835, which means, of course, that the plate is in excess; but the ratio will diminish until it reaches 0.667, when the strength of the plate has become equivalent to that of one only $\frac{1}{2}$ inch thick, as was required. The efficiency of the joint would be 45 per cent., whereas the best efficiency of a joint in $\frac{5}{8}$ inch plate with 1 inch holes ($p=1.84$ inch) would be 50 per cent., and the best possible efficiency of a single-riveted lap joint in $\frac{5}{8}$ inch plate under the given condition of strength would be about 62 per cent. It is hardly necessary to point out how strongly these figures indicate the necessity of using as large rivets as possible, and of taking every possible means to reduce the allowance necessary for corrosion. For a boiler, such as has just been discussed, is absolutely no stronger than one of $\frac{1}{2}$ inch plate throughout, if only the thickness of the latter could be kept unreduced at the joints.

(12). There are now in hand for the Riveting Committee further experiments on double-riveted joints of the general types already tested, in $\frac{3}{8}$ inch, $\frac{3}{4}$ inch and 1 inch plate, designed specially to throw light upon the questions of hydraulic and hand-riveting, high and low-pressure hydraulic-riveting, and the practical value of exceptionally large rivets. They will also give further information as to the slip of joints, and other points already discussed; and may further, it is hoped, be made use of to throw some light on rather more obscure problems—such as those raised recently by Mr. Milton at the Institution of Naval Architects—connected with the stress in the metal of the plate in the neighborhood of the joint.

Although this paper is an unofficial abstract of the result of experiments only, and not an official summary of the whole work of the Riveting Committee, the author may be allowed to call attention, in conclusion, to other memoirs, not reports on experiments, which have been prepared in connection with the work of the committee. Of these the earliest, and by far the most important, is the admirable summary of the published results obtained up to the time when the committee commenced work, by Professor W. Cawthorne Unwin, and published in the "Proceedings" for 1881, pp. 301-368. This paper, along with many valuable suggestions made by its author at the time, formed really the foundation of the whole work of the committee. The table compiled by Mr. Ralph H. Tweddell, showing rules of practice used by manufacturers for riveted joints in iron, published in the "Proceedings" for 1881, pp. 293-299, has proved very instructive. In addition to this, Mr. Tweddell has contributed some remarks on hydraulic riveting to the last report of the committee just issued to members; and Mr. W. Silver Hall has added in the same place a collation of Mr. C. H. Moberly's experiments and a few others, with those of the committee.

DISINTEGRATION OF BUILDING STONE.—The sandstone commercially known as freestone, which is extensively used for building purposes in American cities, is subject to disintegration from the action of the sulphurous acid produced by the consumption of coal and from frost. There is much difference in the ability of various quarries to withstand these destructive influences. The outer surfaces of some buildings in New York and Philadelphia have been, by the advices of an eminent chemist, treated with a mixture of paraffin and carbolic acid with apparently good results. The flat surfaces are warmed by means of a stove like a plumber's stove, but with a flat side, and the paraffin when applied in a melted condition penetrates the stone readily, it is said that in some instances to the depth of $1\frac{1}{2}$ in. Mouldings and carved work are heated by means of a blast flame from india-rubber bags of illuminating gas. Another process has been suggested, but the preliminary results do not appear to be of a satisfactory nature on account of its tendency to crack. In this process the mixture used is an artificial stone, and consists of three parts glass sand, three parts broken marble, two parts anhydrous clay, and two parts freshly slaked lime still warm. After a coat of the above has been applied wash it with water on the following day. The central portion and wings of the Capitol building at Washington were originally built of freestone, which disintegrated so rapidly as to threaten the permanence of the structure, and the whole was protected by several coats of white paint. The wings afterwards added to the above and now used for their House of Representatives and Senate Chamber, are built of white marble, which conforms in color to the central portion of the building, so that the whole building appears to be made of marble.

THE UTILIZATION OF A NATURAL CHALYBEATE WATER FOR THE PURIFICATION OF SEWAGE.

By JOHN C. THRESH, D.Sc.

From the "Journal of the Society of Arts."

The removal of organic matter from water-carried sewage is a subject of such extreme importance, that a description of any process actually being employed, whether completely or in part successful, cannot but be acceptable to all who are interested in sanitary matters. On this account, I have undertaken to lay before you this evening particulars of a process of a somewhat novel character, now being worked at one of our inland health resorts, Buxton, Derbyshire.

The novelty of the process lies in the fact that the waters of a chalybeate spring, flowing from an old coal mine in the district, are utilized for effecting the precipitation and purification. Until after the public opening of the works in question, I was unaware of any similar system of sewage treatment having been attempted. Since then, it has been brought to my notice that at Prestwich, near Manchester, an iron water from a neighboring colliery is caused to mix with the sewage from some forty cottages, and after passing through a number of tanks, the effluent runs into the brook. Whether anything is added besides the iron water I have not been able to ascertain, neither do I know whether the condition of the sewage and effluent has ever been reported upon.

The Buxton sewage is entirely "domestic" in character, there being no factories or works of any kind turning their waste products into the drains. The amount probably averages over 400,000 gallons daily, but varies very considerably, sometimes sinking as low as 300,000 gallons, and at other times rising to 1,000,000 gallons. Considering that the population of the place is only 7,000, these amounts appear enormous, but it must be remembered that during the season (May to November) there are constantly from 1,000 to 5,000 visitors also in the town. Besides this, most of the water from the springs, for which Buxton is famous, finds its way into the sewers, certainly not less than 100,000 gallons from this source being added daily to the sewage, and a considerable amount of storm water also passes into the drains and assists in diluting the sewage. Were it not that during storms the flooding of the sewers brings down an immense amount of offensive matters, the sewage at such times would be excessively dilute. At the present time no change in the drainage is contemplated, but should it appear desirable for any reason to diminish the volume of sewage to be treated, the whole of the bath water could be easily diverted into the river.

Several schemes for purifying—or at least clarifying—the sewage have been tried and abandoned, and for some years the whole has been allowed to run directly into the river without being subject to any treatment whatever. This river, the Derbyshire Wye, rises only a little distance beyond the town through the middle of which it flows; and as in dry seasons the volume of water in the stream is fully doubled by the addition of sewage, its condition in the hot weather is better imagined than described. The adoption of the process of treatment with iron-water and lime, an account of which I am now about to give, has resulted in considerably improving the character of the stream, and there is little doubt that this river will henceforth cease to create a nuisance in the lovely valley through which it flows.

Briefly stated, the sewage is treated by mixing with about one-third of its volume of a natural chalybeate water, to which a certain amount of milk of lime has been added, and allowing the mixture to flow into a series of tanks, in which the precipitated matter collects, whilst the clear effluent flows over a weir at the end into the river.

It will probably conduce to lucidity if the whole process, &c., is described systematically, and in the following order:

1. Construction of the works.
2. The chalybeate water.
3. Action of this water on sewage.

4. The sewage before and after treatment.
5. The matter precipitated (sludge).
6. Cost of construction and maintenance of works.

1. *Construction of the Works.*—The following brief account of the works is taken from a report of Mr. Hague, Assoc. Inst. C.E., the town surveyor, from whose plans and under whose supervision the whole has been constructed:

The iron-water employed is conveyed by gravitation in especially made earthenware tubes, from a disused colliery at the foot of the Axe Edge hills. At a short distance from the "heading" entrance to the colliery, the iron-water enters a brick receiving tank, constructed on the edge of the brick course nearest the colliery, and is conveyed across the brook in 9-inch metal pipes supported on stone piers. Thence it takes a northeasterly direction to the site of the works, a length of 2 miles 163 yards, and enters a second tank at the rear of the liming rooms adjoining the works, which are situated between the River Wye and the Midland Railway, in Ashwood Dale.

The liming and mixing rooms are erected over the River Wye, supported by a stone semi-circular arch, the liming room floor being on a level with the adjoining highway, and connected with the Board's sidings on the Midland Railway.

The lime required for precipitation purposes is conveyed from the sidings alluded to to the hopper of a patent liming machine. A cistern of 800 gallons capacity receives the pulped lime from the machine, and is supplied with an agitating apparatus, to keep the lime required during the night of a uniform and suitable consistency. Both the machine and agitating apparatus, &c., are driven by an "overshot" water-wheel, 16 ft. in diameter and 3 ft. wide. The water for driving purposes is taken from the Wye, about 500 yards higher up the stream, and conveyed in large sanitary tubes.

Immediately outside the liming and machinery rooms are constructed duplicate brick tanks, into which the main outlet sewer discharges. The tanks are furnished with wrought-iron screening wagons, for the purpose of abstracting the solid and floating matter. After passing through the screening wagons the sewage runs through a brick conduit into a circular metal chamber, furnished with horizontal paddles, where the iron, lime, and sewage are thoroughly mixed. From here the sewage flows a distance of 50 yards, through an earthenware conduit, to the settling tanks, consisting of two sets so arranged as to work either singly or together. Those tanks are constructed of brick walls set in cement, with concrete bottoms, the walls being coped with dressed local grit stone. The length of the tank is 266 ft., and width 73 ft., and they are capable of holding 400,000 gallons. The formation of the tank bottom is of original design, being 3 ft. 6 in. deeper at the entrance than the outlet, an arrangement which has fully met the object for which it was introduced, that is to retain the sludge at the inlet end of the tanks. The first of those tanks is formed with a brick division wall six feet from the inlet, supported on arches of a similar material, under which the sewage flows into a second tank, and thence through the entire series of tanks, with a barely perceptible motion, to the effluent weir sill.

In the center of the main division wall, at the inlet end of the tanks, a triangular well is constructed for cleansing purposes, and is supplied with duplicate iron run-off cloughs, so arranged as to remove what water remains, owing to the extra depth of the tanks at that end, after the suspended matter has subsided. Outside the entrance tank is a sludge well, fitted witth a strong chain pump, driven by water power, and with cloughs so arranged as to remove the sludge. It should be stated that the bottom of the tanks is formed with a longitudinal and transverse inclination, with the view of expediting the cleansing process, and minimizing manual labor.

2. *The Chalybeate Water.*—The mineral water mentioned as being utilized in this process of sewage purification is derived from a spring which arises in the so-called "old level" mine at Burbage, about two miles beyond Buxton, a mine driven in one of the beds of shale between the mountain limestone and the Yoredale rocks. Until recently diverted, the water flowed into the Wye, very near its source, covering the bed of the river for some distance with a yellow deposit of ochre. The flow of water varies somewhat considerably, but even in the driest seasons

there is always an abundant supply, probably never less than 100,000 gallons in the 24 hours. The amount of salts in solution is almost as variable as the flow, undoubtedly due to the fact that the stream in its course from its origin in the mine, to the point where it issues from the hill side, is diluted with water which percolates through the strata above, the amount of such dilution varying of course with the rainfall.

The water has always a faintly opalescent appearance, and if exposed to the air an ochery deposit very rapidly subsides. The sample which I submitted to careful analysis, and the results of which are now given, was collected during a somewhat wet summer, but at a time when no rain had fallen for several days previously. As besides sulphates the water contains only a small proportion of carbonates and a trace of chlorides, there is little room for theorizing as to the nature of the salts in solution.

Each gallon was found to contain—

	Grains.
Silica	1.44
Ferric oxide	.28
Ferrous sulphate	3.30
Aluminic "	1.26
Magnesium "	7.44
Calcium "	9.01
Sodium "	1.99
Ferrous carbonate	3.22
Sodium Chloride	.76
	28.70

[The total iron corresponds to 14.8 grains of the crystalline sulphate, and the alumina to 3.6 grains of potash alum.]

From the estimations of the iron made at various times, I find that, as a rule, the water is not nearly so strongly chalybeate as this sample, but the analysis gives us an insight as to the nature of the constituents and their relative proportions. It may not be without interest to mention that on the other side of Axe Edge, the hill from which this spring arises, there is another chalybeate spring very much more powerful, containing in each gallon 299 grains of solid matter, of which 174 grains are ferric sulphate, and 73 grains aluminic sulphate. The flow, however, is not nearly so considerable, and to convey it to Buxton would have been a task of some magnitude.

3. *Action of the Chalybeate Water on Sewage.*—When the iron-water is mixed with from two to four volumes of (Buxton) sewage and allowed to stand, a deposit slowly forms, but even after many hours the mixture does not become perfectly clear, in fact it remains cloudy for days. An examination of the supernatant fluid shows that a considerable amount of organic matter remains suspended and in solution, but that some has been removed.

If, however, lime be mixed in proper proportions with the iron-water and sewage, then a more or less flocculent precipitate at once forms, the rapidity with which this settles depending upon the order in which the ingredients are mixed, and the amount of agitation received. The best results in the laboratory were uniformly obtained by adding lime in the proportion of 15 grains to one gallon of the ultimate mixture to the iron water, and then pouring this into the sewage, and stirring gently for half-a-minute to a minute. Under these circumstances, the flocculæ first formed aggregate together, and fall to the bottom of the receptacle with the utmost rapidity. If the stirring be neglected, the flocculæ are small and subside very slowly; if the agitation be too violent, these large flakes are either broken up or prevented from forming, and clarification is again retarded. Analysis of the effluent, when clear, invariably proves the greater part of the impurities to have been removed in the precipitate. As showing the marked improvement affected by addition of the lime, the result of a typical experiment may be quoted.

For fifteen hours the sewage and iron-water, unmixed with lime, were allowed to flow through the tanks, and at the expiration of that time, a sample of the effluent (1) was taken. The liming machine was now set in motion, and after twenty-four hours, another sample of effluent (2) collected. The results of the examination of the sewage and the two effluents are here compared.

	Organic Ammonia.	Free Ammonia.
	In parts per Million.	
Sewage (mean)	5.	13.
Effluent (1) turbid	1.7	5.
" (2) clear	.7	3.9

Working at the tanks, it is found that less lime is required to effect clarification than had been calculated to be necessary from laboratory experiments. As nearly

as can be ascertained, twelve grains of slacked lime to a gallon of mixed iron-water and sewage secures efficiency, and is the proportion now being added. An excess of lime is distinctly prejudicial; a flocculent precipitate forms, and begins to subside, then the whole volume of fluid gradually becomes opalescent (apparently from formation of calcium carbonate), and then only clears after a considerable lapse of time.

4. *The Sewage before and after Treatment.*—To illustrate the character of the sewage and of the effluent produced, the results of the daily examination of both for one week have been tabulated. The samples were collected alternately in the morning and afternoon:—

RESULTS EXPRESSED IN GRAINS PER GALLON.

	Total solids.	Alb. NH_3	Free NH_3		Total solids.	Alb. NH_3.	Free NH_3.
Sewage.	..	.31	.83	Effluent.	23.	.05	.19
"	37.	.33	1.05	"	28.	.05	.51
"	37.	.22	.65	"	25.	.04	.18
"	51.	.36	1.16	"	28.	.07	.24
"	39.	.23	.76	"	27.	.06	.27
"	56.	.32	1.01	"	26.	.04	.38
"	37.	.26	1.12	"	27.	.04	.17
Mean...	43.2	.29	.94	Mean ...	26.3	.05	.28

A more complete analysis of a typical sample of sewage and of the corresponding effluent, yielded the following results:

	Sewage. Grains per gallon.	Effluent. Grains per gallon.
Total solids (solid at 212°F.)	36.1	26.5
Loss on ignition	13.3	5.5
Chlorine	3.	2.2
Free ammonia	.60	.24
Alb. "	.22	.04

	Sewage. Grains per gallon.	Effluent. Grains per gallon.
Hardness, temporary	10.	6.
" permanent	4.	11.
Total	14.	17.

Nitrates and nitrites present in only small quantities in both.

Upon comparison, it will be noticed that in the sewage the total solids varied from 37 to 56 grains per gallon, with an average of 43 grains; in the effluent from 23 to 28, with an average of 26. In the sewage the albumenoid ammonia varied from .22 to .36 grains, with an average of .29; in the effluent, from .04 to .07, with an average of .05. The free ammonia in the sewage varied from .65 to 1.2 grains, average .94; in the effluent, from .17 to .51, the average being .28.

With regard to the alkalinity of the effluent, I have refrained from expressing this numerically, for fear of fostering a misconception. If by alkalinity we mean presence of uncombined alkali (ammonia and lime), then I have never observed the sewage to be alkaline. On no occasion has an alkaline reaction been indicated on adding a little phenol-phthalein as indicator; on the contrary, it has invariably been necessary to add more or less alkali to produce the pink tint. Moreover, the presence of calcium carbonate is always demonstrable by comparing the permanent with the total hardness.

When an indicator, such as methyl-orange, is employed, no acid reaction is exhibited; indeed, a certain amount of acid must always be added before coloration is produced. This, however, does not prove the presence of free alkalies, inasmuch as with such indicators no reaction is obtained until all the carbonates have been decomposed.

This distinction between alkalinity due to presence of free alkali and carbonates, is one of some importance in treating of sewage effluents, as to whether they are in a fit condition to cast into a stream; and I have more particularly made reference to it here, because I have seen it stated that the effluent from the Buxton sewage was "distinctly alkaline," and commented upon as though this alkalinity was due to the presence of lime.

The amount of lime salts in solution, both in the sewage and effluent, may be inferred from the results of the examinations for hardness. As a rule, the sewage varied within the following limits:—

Temporary hardness	8—12
Permanent hardness	4— 6
Total	12—18

The effluent similarly gives—

Temporary hardness	6— 0
Permanent hardness	10—20
Total	16—20

In treating sewage with lime alone, if sufficient be added to effect anything like clarification, the effluent is almost inva-

riably and truly alkaline, but in the scheme under consideration, a considerable portion of the lime is used up in decomposing the salts of iron, aluminum, &c., in the chalybeate water, a little doubtless is carried down with the precipitate thus produced, without entering into any combination or effecting any decomposition, the remainder attacks the soaps, fatty acids, and free carbonic acid in the sewage, throwing out of solution also an equivalent of calcium carbonate by the withdrawal of the acid gas which had held it in solution. Thus, while the permanent hardness is increased, the temporary hardness is reduced, the total hardness being but slightly affected.

Returning to the organic matter in the sewage and effluent, as measured by the free and organic ammonia, in order to ascertain what improvement is due merely to dilution, and what to the action of precipitating agents, we have only to know the relative proportion of iron-water used and make a simple calculation. During the week for which the results of the daily examination of the sewage have been recorded, as near as I can ascertain, the volume of iron-water would be about one-third that of the sewage. Correcting for this dilution, we find the organic ammonia reduced from .29 to .07, and the free ammonia from .94 to .37 grains per gallon, *i.e.*, the organic ammonia is reduced to less than one-fourth, and the free ammonia to one-third, results which, considering the character of the sewage, must be regarded as satisfactory. With a sewage exceptionally strong (for Buxton), the decrease is very much more marked.

Inevitably from the relative volumes of the sewage and water, the condition of the stream into which the precipitated sewage flows must be largely influenced by that of the effluent. The improvement in the river became apparent almost the moment the works were put into operation. Immediately before the sewage was turned into the tanks, a sample (No. 1) of the river water was taken about 200 paces below, and afterwards a sample (No. 2) when the sewage was running into the tanks and the effluent into the river. Upon analysis these gave the following results:

	Grains per Gallon.	
	Free ammonia.	Organic ammonia.
No. 1	.29	.15
No. 2	.09	.02

Showing that the improvement was most marked.

Compared with the action of solutions made to imitate in composition this natural water, it is invariably found that the latter, under the same conditions as to agitation and quantity of lime added, give a more flocculent precipitate, subsiding with greater rapidity, and yielding a brighter effluent than is the case with the artificial water. As previously stated, the best results are obtained by adding the lime to the chalybeate water, and immediately pouring the mixture into the sewage, with due agitation. Frequently the sewage can be quickly cleared in this way, when it absolutely refuses to clear if the lime be added to the iron-water and sewage previously mixed. The probable explanation of this somewhat singular fact appears to be, that the action which takes place during purification is not only chemical but mechanical. Upon adding the lime to the undiluted iron-water, a copious flocculent precipitate at once forms, and when poured into the sewage, these hydrates (and carbonates?) combine with certain of the organic constituents of the sewage, aggregate into large flocculæ, taking up at the same time the matters which are suspended, and carrying the whole to the bottom. When the lime is added to the iron-water, diluted with 2—4 volumes of sewage, the precipitate which forms is only slightly flocculent, and rarely aggregates by agitation; hence it does not free sewage of the matters suspended in it.

Apparently, also, by adding the lime to the iron-water first, a smaller quantity of the alkali is required to affect the purification. This is probably due to much of the lime entering at once into combination with the free carbonic acid of the sewage, and being thus rendered incapable of acting upon such a dilute solution of iron, aluminum, and magnesium salts.

5. *The Sludge.*—Notwithstanding that not a particle of insoluble matter is used in this process, the amount of sludge produced is somewhat considerable, and unfortunately, as yet, I have been unable to persuade the local authorities to take

any steps to make it more disposable. At the present time it is simply pumped from the well (by the chain-pump worked by a water wheel), after draining from the tanks as much water as possible, and carted away to the board's farm. The members of the board are sanguine that its effect as a manure will be such, that the local farmers will be glad to fetch it away when the tanks are being cleansed. If such is the case, and they do not care to try and make it into a salable commodity of any kind, then, so far as they are concerned, the sewage problem is solved. It is suggested that the "destructor" they are about to erect to burn the town's refuse should be so adapted as to dry, and, if necessary, burn the sludge, as the ash, which consists of lime and ferric oxide chiefly, can probably be utilized. As the sludge is apparently not nearly so slimy as that produced by lime alone, it would not be so difficult to convert it into a salable manure.

As nearly as can be ascertained, the perfectly dry residue from 1,000,000 gallons of sewage and iron-water will be 25 cwts., but as the sludge, as lifted by the pump, contains at least 75 per cent. of moisture, five tons of such sludge would be deposited. Taking the amount of liquid flowing through the tanks to average 600,000 gallons per day, 21 tons of sludge would be formed weekly. This, by drying, would be reduced to six tons, and by incineration to about three tons.

The sludge varies somewhat in composition, but when sufficiently dry to be pulverulent, its average composition is as under:

Moisture	15.
Organic matter	38.
Oxide of iron and alumina	14.
Calcium and magnesium carbonates	24.
Phosphoric acid	1.
Other mineral matter	8.
	100.

The nitrogen present corresponds to 1.5 per cent. of ammonia.

6. *Cost of Construction and Maintenance of Works.*—The original estimate for the construction of the tanks, erection of three workmen's cottages, conveying the iron-water, laying of tramway, and for machinery, was £3,000. This, however, is likely to be slightly exceeded, but if the cost of the cottages is deducted, £3,000 will more than cover the remainder.

Very little labor is required to efficiently carry on the works; one man being able to attend to the lime, machinery, and the emptying of the cages in which the larger solids are collected. When the sludge is being removed from the tanks, a little additional help is required. The total cost per annum for labor may be put down at £75. The only additional expense is the lime, the cost of which will be about £80 yearly. The total expense, therefore, including interest on capital, is £275 per annum, made up as follows:

Interest on £3,000, at 4 per cent.	£120
Labor	75
Lime	80
	£275

Taking the population of the town at 7,000, this involves an annual charge per head of 9½d., or as it is put in the official statement by the Board, "the cost of the system, including the erection and maintenance of the works, will be covered by a rate of 1¾d. in the pound." Put in other words, each million gallons of sewage treated cost the ratepayers £1 5s.

Having given all the actual details of the process as now being worked, I would again, in conclusion, draw some attention to the fact that the action of this chalybeate water differs from that of a mere solution of sulphate of iron and alumina of corresponding strength in the important particulars, that, when mixed with lime (in due proportion) and added to sewage, it precipitates the suspended and dissolved organic matter (1) more rapidly and (2) more completely, removing the whole of the former and considerable portions of the latter. Moreover, in using alumina and iron salts for sewage purification, the best results are always said to be obtained if the sewage is dosed with lime before these salts are added; whereas with the natural water such is not the case, the maximum efficiency being apparently secured by adding the lime to the iron-water, and then mixing with the sewage. If after adding the lime the mixture be allowed to stand a short time before pouring into the sewage, its efficacy is impaired, or even altogether destroyed.

In the natural water, it must be remembered, we have not only ferrous sulphate, but also ferrous carbonate, and there is

considerable probability that the compound plays a more important part in the purification of water by iron and its salts than has been hitherto suspected. It is well known that the mere immersion of metallic iron in an organically polluted stream tends to purify it, and possibly this may be explained by the action of carbonic acid on the metal, and of the resulting compound on the organic matter.

A series of experiments bearing on this and other points connected with the subject are now being conducted, the results of which cannot be without interest, and may probably be of considerable importance.

DISCUSSION.

Mr. Baldwin Latham said there was nothing particularly new in this process, but he thought it was a mistake to mix the lime-water with the iron-water before the mixture went into the sewage. At the town of Horsham the water supply contained a large quantity of iron, and he found that the whole of that iron could be precipitated by the addition of lime. It appeared, therefore, to him that mixing iron with the lime before passing it into the sewage would produce an inert compound; and all recent experience showed that wherever lime was used, it should be added before other chemical compounds, especially where such compounds were of an acid description. Very great improvements had taken place in many sewage works by simply putting in the lime first before the sulphate of alumina, much less chemical being required, and more satisfactory results being obtained. Although the quantity of chemicals used in this Buxton experiment was large, the expense would be considerable if the same process were applied to a large town, and they had to purchase chemicals. One volume of this material was added to two volumes of sewage. This dilute water, containing no sewage, and from which all the salts were precipitated, would give about twenty-eight grains in the effluent without any chemical, as against twenty-six produced by the process; so that the degree of purification due to absolute admixture was very great by using this large volume of water from which the material had been precipitated under the action of lime. It was a well-known fact that if you could always command sufficient water to mix with sewage, then no chemical process was required, because one volume of sewage to four of pure water would give an effluent purer on the average than the best results shown by irrigation, which was acknowledged to be the best system. The tank space employed was very large for the volume of sewage stated, and he could not understand how this sewage was so strong as it appeared to be, unless there was some large amount of solid matter in the water supply. If both these tanks were in use, they would contain the sewage for twenty-for hours, which gave a long time for sedimentation to take place. Iron in various forms had been used repeatedly, and from investigations made some years ago for the Commission on Metropolitan Sewage, it was shown by Dr. Frankland that of all the salts of iron perchloride was the best, but that utterly failed when it came to be tried over a number of years. At Northampton that process had been adopted in conjunction with lime, but the river became so foul that it had to be abandoned, and the sewage applied to land. In fact, the iron had been almost universally abandoned, one reason being that sludge containing a large amount of iron was supposed not to be so valuable for agricultural purposes. The paper was interesting as recording an experiment; but he feared when the parties in this particular neighborhood wanted an effluent of a high standard of purity, they would find some other method would have to be adopted. He should like to know what means were taken for regulating the chemicals which passed into these tanks, as he understood they were left to work by themselves at night, when probably the sewage would be less in quantity and more diluted. But as the strength of sewage varied, so should the amount of chemicals vary, and in all the works with which he was connected where chemicals were used there was an automatic arrangement worked by the sewage itself, so that the right volume should be added. Under ordinary circumstances, the flow of sewage at one period of the day would be three times as much as the average flow, so that the adjustment of the amount of chemicals was very important. He thought the large number of divisions in the tank was probably a disadvantage, as it would be impossible to rectify a mistake. If too

little chemicals went into one compartment it might be nearly filled with raw sewage, which would ultimately pass out in the same state. But if there were no impediments in the tank, it would be possible by large admixture to greatly modify the ill-effects due to bad judgment.

Prof. Bischof remarked that when Dr. Frankland made his experiments, and found that perchloride of iron was the most efficacious in purifying impure water, he did not extend his experiments to the ferrous carbonate and hydrate, and he believed that these salts were the most efficient in removing organic matter from water. If, however, these were used, he quite agreed with Mr. Latham that you should not attempt, to neutralize the action of the iron by first adding lime. He had tried this by adding soda, and always found the purifying action was considerably decreased. He had had a rather extensive experience in connection with purifying water with iron. Some time ago he noticed at the Antwerp waterworks that after the water had passed through the spongy iron filter, when it entered the second sand filter—because with potable water you must have a second filtration—peculiar flakes appeared in it, some of which he was able to collect for analysis; they were about the size of half-a-crown, and very much resembled dried leaves. After drying them at a temperature of 120° Centigrade, he found that the dried residue contained 49 per cent. of peroxide of iron, and after that was dissolved with dilute hydrochloric acid, what remained was incinerated, and scarcely left any residue whatever. It appeared to be something of a silicious nature, but it was impossible to test it qualitatively. This was an instance in which an insoluble compound, formed by certain organic acids, such as uric acid and hippuric acid, which all formed insoluble compounds, with ferrous or ferric salts was separated almost with the same definiteness with which you could separate a crystal. Returning to the paper, it seemed to him there was an over-abundance of iron present, because in very impure water he had found two milligrammes per liter of ferrous hydrate, or carbonate, calculated as ferric peroxide, were sufficient to effect purification. He should like to have seen a determination of the ammonia in the ferruginous water, which was very essential, to show the purification effected by the iron and lime. He would also ask whether it had been found that the sewage, after having been thus treated, could be kept for a length of time without undergoing decomposition. This was a most important question, the destructive action of iron on microphytes. That this action took place was now beyond doubt. This had been shown by him in various papers, and the late Dr. Voelcker stated in one of his papers that the presence of a proto-salt of iron in the soil was a sure sign of barrenness. These organisms in sewage were mostly, at any rate, plants, and probably were acted upon in the same way as the higher plants. This view had been confirmed by Dr. Griffiths, who found that by manuring wheat with sulphate of iron it was freed from mildew, but he also found that when he added too much sulphate of iron he destroyed the wheat itself.

Dr. Percy Frankland wished to remark, in reference to what had been said by the last speaker, that the perchloride of iron, used by his father in the experiments made for the Rivers Pollution Commission, was only nominally perchloride, and that on analysis it was found to consist principally of proto-chloride. Therefore, on the addition of lime, there would necessarily be principally ferrous hydrate present, and he presumed purification would take place by means of that, and only to a less extent by the ferric hydrate. With regard to this water at Buxton, it was obvious, from the interesting paper which they had heard, that unless there were a very large excess of this purifying material present, it would be exceedingly unsuited for the purification of sewage, because it appeared that not only was the volume very variable, but the composition equally so, so that by no automatic device could it be arranged that the reagent should be duly proportioned to the sewage. This mode of purification by means of iron was a very old one. In fact, the composition of this chalybeate water appeared to be the inverse of that of the reagents which were used in some other sewage works, for instance, at Leyton, where the alumina added corresponded to the quantity of iron present in this water, and the quantity of alumina here corresponded to that of iron there. The proportions used at

Leyton were about 12 grains of lime, 2½ proto-sulphate of iron, and 10 grains alum per gallon of sewage. Contrary to the practice at Buxton, it was usual there to add the lime in the first instance, and then the other re-agents. It was exceedingly remarkable that a better result was not obtained when the mixture between the iron and the lime took place after admixture with the sewage. It was obvious that this Buxton sewage, however, was about one-tenth the ordinary strength. With regard to the analysis of the sewage before and after purification, he should like to ask Dr. Thresh whether he had taken care that the samples of the effluent should correspond with the samples of of raw sewage examined, because the albumenoid ammonia given in the effluent appeared to be very constant, and not to vary with the time of collection; that collected in the afternoon containing the same quantity as that collected in the morning. It was a pity the analyses were not more complete. There were no determinations of organic carbon and nitrogen, which would have rendered the testing of the process far more conclusive. Again, it would have been desirable that the amount of chlorine in the raw sewage and the effluent should be determined, because it was only by taking into account some mineral ingredient, which could not be removed by any re-agent, that one could be at all sure of the relative dilution of the sewage before and after treatment. Dr. Thresh appeared to lay a great deal of stress on the disappearance of ammonia in this process, but he should like to ask him what, in his opinion, became of it. He did not see how it could be precipitated, and if not, it was not of much consequence what became of it. Probably it passed away into the air; in fact, in nearly all these precipitation methods, one found a considerable reduction in the amount of free ammonia; whilst if the process was tested in the laboratory, where the mixture was made in a stoppered bottle, the ammonia remained practically constant. For instance, in one case he himself had found sewage that contained 5.5 grains of free ammonia per 100,000 parts, when the actual effluent contained only 1.75. But when the same process was tried on a small scale, the ammonia was only reduced to 4.75, or scarcely at all. At any rate it did not appear to pass into the sludge, as the amount of nitrogen found there was much less than the ammonia which had disappeared would yield. It was very desirable that this sludge should be filter-pressed. The great objection to all these precipitation works was the accumulation of sludge, and the nuisance occasioned when it was air-dried, but this was almost entirely abolished if it were filter-pressed. He noticed that the local board expected to obtain a sale for the ashes of this sludge, which consisted principally of oxide of iron and lime, but he did not think these materials would find much sale near Buxton, which was already so abundantly supplied with them.

Mr. Ekin said Dr. Thresh had probably two main objects in view in this paper; first, to point out to local boards who were fortunate enough to have a chalybeate spring in their neighborhood what could be done with it; and, secondly, to show that there were indications here of new methods of water purification which were very promising. With regard to the use of chalybeate springs from mines for mixing with sewage, he had experience some years at Worseley, in Staffordshire, where an action was brought by the riparian owners against the Local Board on account of an enormous amount of sewage being poured into a sluggish stream; but there was no difficulty in proving that a small brook, which was fed from a mine near, and was very rich in iron, completely destroyed the sewage in the course of a very short run. He had followed Dr. Thresh's experiments, and really thought there was some hopeful indication in this particular mixture of a solution of the sewage problem. Certainly, as far as they knew, nothing had ever given such an absolutely clear effluent. The effluent at Buxton was exactly like sparkling spring water, a result which he had not seen anywhere else. Mr. Baldwin Latham had rather objected to this as simply an iron process, and he was so well read in all matters relating to sewage that he (Mr. Ekin) was rather surprised to find that he was not quite up to date in objecting to iron for making the sludge useless; for some remarkable results had been lately given before the Chemical Society, which showed that in certain proportions iron was exceedingly valuable as manure. But

this was not an iron process alone; there were aluminum, magnesium, calcium, &c., and some experiments of his own, on a small scale, with a similar mixture of salts, seemed promising. Iron salts alone certainly would not give anything like the same results. Dr. Thresh had been very candid about the whole matter, having given in other places ample details of his experiments. He had worked very industriously at the composition of this spring, and had not been able to produce by any mixture of salts what this chalybeate water would undoubtedly do, but he hoped he would still persevere until he found out the secret of this particular combination, whatever it might be. With regard to the cost of the ingredients, he did not know that they need be at all prohibitive. If the Metropolitan Board of Works could afford to deodorize London sewage with potassium permanganate, he thought he could promise that a mixture of this kind would be considerably less expensive. Of course the old difficulty of the sludge cropped up, and he thought twenty-one tons per week for such a small town was rather large. Filter-pressing might be very useful, but that certainly seemed the difficulty with all sewage operations.

Mr. Baldwin Latham said that at Leyton the iron and aluminum process had been abandoned, and lime and black-ash waste was now used, which had certainly the remarkable property of preventing the sewage effluent undergoing a change.

Mr. Maxwell Lyte said, as regards the cost of the ingredients, he understood that alumina was one of the ingredients in these chalybeate springs. Hitherto, in the A B C process and others, alumina had been the chief precipitating agent, but his father had taken out a patent for the use of aluminate of soda in conjunction with sulphate of alumina, and by that means was able to effect a saving in the precipitation of alumina, or hydroxide of alumina, of about 33 to 50 per cent.

The chairman said anyone who had had much to do with the treatment of sewage would know that there were a great many points on which a very substantial agreement existed, whilst there were other points on which opinions were widely opposed. There could be no doubt of the accuracy of the statement made by Mr. Latham, that sewage irrigation when satisfactorily carried out, did produce a purer effluent than the process of precipitation, also supposed to be well carried out. The only question was, whether the process of precipitation, in certain cases, effected a sufficient amount of purification for the purpose; and here, again, although there were diverse opinions, the preponderence of opinion was that the process did, in many cases, effect sufficient purification. With regard to the particular precipitant to be employed, he did not gather that Dr. Thresh recommended that every town should carry out expensive engineering works to bring chalybeate water from a distance, when they could get their chemicals in a much more concentrated form, but he did think that great praise was due to Dr. Thresh for having taken advantage of the special opportunity afforded him by the proximity of this natural water. Of course there were advantages and disadvantages attending the use of a chalybeate spring. One advantage was that it could be obtained practically for nothing; but on the other side was the disadvantage that you had to deal with a very bulky material, necessitating increased size of tanks, and you were also dealing with a material somewhat uncertain in quantity and composition. On which side the ultimate advantage lay, could only be decided by experience. It would seem, on the face of it, that this water containing iron in the two forms of sulphate and carbonate, also appreciable quantities of alumina, and large quantities of magnesia, was pointedly fitted by nature for this particular purpose. As regards the order in which the chemicals were mixed, and the observation of Dr. Thresh with regard to the effect of an insufficient or extreme amount of agitation, those were entirely practical questions. So far as his experience had gone, it accorded with Mr. Latham's, that the best results were obtained by the addition of lime first, and the subsequent addition of alumina, or alumina mixed with iron; but how far it would necessarily follow that a similar course would be best where the iron was already dissolved in such a large excess of water, was an altogether different matter. He should have preferred a little more information on one or two points with regard to the nature of the sewage, and the chemical character of the ef-

fluent; and he would refer more particularly to the removal of insoluble organic matter by the process. Substantially the whole of the insoluble matter in sewage was capable of being removed by precipitation, together with a certain proportion of the soluble. Authorities differed whether the removal of the soluble or insoluble matter was most important. For himself, he entertained the opinion, which was rather opposed to that of Dr. Frankland, and the Rivers Commission, that the removal of the insoluble matter was the most important of the two, but this was an open question. Still, in dealing with precipitation schemes, it was to be borne in mind that you could certainly effect the removal of substantially all the insoluble organic matter, together with a certain variable proportion of the soluble. There was a great deal yet to be learnt with regard to the best mode of dealing with sewage; and they would all recognize that Dr. Thresh had made an important, ingenious, and, in this particular case, an exceedingly successful addition to their practical knowledge on the matter.

Dr. Thresh, in reply, said Mr. Latham seemed to have misunderstood the motive he had in making this communication. He claimed no originality, but the fact was, that in consequence of the opening of the sewage works being published, he had received innumerable letters asking for particulars of the process and in some cases for minute details. As it was impossible for him to reply to all these letters, some of his friends suggested that the best thing he could do was to read a paper before some society, and the secretary of this section had kindly fallen in with that idea. At Buxton, certain schemes had been tried, and having been requested to report upon them, and having condemned some of them, he was asked if he could suggest something better. It was acknowledged that this iron spring was a nuisance, as it covered the bed of the river with ochre, and rendered it unsightly. It then appeared to him that if they could make one nuisance remedy another, it would be a benefit to the town. Consequently, he undertook experiments, and found that by the addition of a little lime they could cause one nuisance to remove the other. Irrigation, of course, was out of the question at Buxton, as there was no land there with a depth of soil exceeding six inches. It was suggested that they should pump the sewage a little distance out of the town, and let it down a water swallow; but no one could say that would be a satisfactory way of getting rid of it. With regard to the effluent keeping without decomposition, some small fish had been kept in a tank, in a mixture of effluent with two volumes of river water, and after lapse of some weeks, they appeared quite healthy, and there was no perceptible smell from the water. It might be a mistake to mix iron-water with the lime first in the case of artificial mixtures of iron and alumina; but in this case, there could be no doubt of the result of his experiments. He did not know that he had hit on the right reason for it, but there was no question that when the lime was added first it did precipitate more rapidly. If you let mixtures prepared in both these ways stand for a few hours, and then examine the effluents, there is no difference with regard to purity, but when the lime was added first, the precipitation took place more rapidly. If you made a solution of sulphate of iron, and made the same experiments, you did not get the same result. With regard to chlorine, he had made a number of determinations, but did not think them sufficiently interesting to record. There was here a natural water which acted in some way which could not be quite explained, but that did not alter the fact that it did so act, and he thought it quite possible that the mode of mixing he suggested was really better than adding lime first to the sewage.

Dr. Bischof asked if the effluent was always free from iron.

Dr. Thresh said not invariably. The process was allowed to go on day and night, and sometimes the lime did not drop through the hopper, and then next day you might find a little iron in the effluent, but it did not exceed a very minute trace, and no notice was taken of it. A small trace like that would not materially affect the purity of the river.

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS—ANNUAL CONVENTION OF 1885.—The annual convention of this Society for the year 1885 will be held at Deer Park, Md., on the

line of the Baltimore & Ohio Railroad, June 24th, 25th, 26th and 27th, 1885. Sessions for professional discussion, and one for the transaction of business, will be held.

All members who can do so are invited to arrive at Baltimore on Monday, June 22d, and take part in the excursion named below.

The sessions will be held during Wednesday, Thursday, Friday and Saturday, except that on one of those days, to be specially announced hereafter, an excursion will be made by invitation of the B. & O. R. R. to the Cheat River Grade, Kingwood Tunnel, Tray Run Viaduct, and other interesting points on the Mountain Division of the Road.

ENGINEERS' CLUB OF PHILADELPHIA—REGULAR MEETING, May 16th.—Mr. Kenneth Allan exhibited and described an improved protractor, designed by Mr. John R. Freeman, Member A. S. C. E., Lawrence, Mass., and made by Messrs. Darling, Brown & Sharpe, Providence, R. I., with special regard to accuracy and finish. It consisted of a plate $6'' \times 12''$, bearing an 11" semicircle graduated to 20 min. The vernier, reading to minutes, is carried on an arm, through the center, to which may be accurately attached different arms, 20" long, graduated to mm., $\frac{1}{1000}$ ft., $\frac{1}{50}$ in., $\frac{1}{40}$ in., $\frac{1}{10 \times 5}$ in., and $\frac{1}{5 \times 10}$ in.

The error from eccentricity of center is determined within $\frac{1}{4}$ min. The total error at any part of arc is believed to be less than $\frac{1}{2}$ min. In use, 100 angles are easily plotted in an hour, and in a year's work its price—$130—is estimated to have been saved. The whole is of nickel-plated steel.

Mr. Dana C. Barber, Assistant Engineer of the Philadelphia Water Department, in charge of Sanitary Surveys and Investigation of River Pollution, presented an account of the pollution of the Upper Schuylkill, being a brief *resume* of some of the more notable and peculiar features, viz., the acid pollution from the coal mines, the cesspool drainage of Reading, the Pottstown water supply, the winter disturbances in the quality at Phœnixville, the drainage of State Insane Asylum at Norristown, etc.

The sulphuric acid from the mines about Pottsville has been decreasing since 1868, on account of the transfer of mining operations to the other side of the mountain, draining into the Susquehanna, and now amounts to but one-third of its former quantity. The most now comes from the region about Tamaqua. But few fish live in the river above Reading, and the water is unfit for use in boilers. At Reading the acid is neutralized by lime-water from Tulpohocken Creek, sulphate of lime being formed and deposited. The water just below Reading would be very pure but for the foul drainage from that city—the greatest source of pollution in the valley. The most peculiar feature there was the underground strata of cavernous limestone, into which nearly half the cesspools and privy wells are dug, and thus drained of liquid waste by natural subterranean channels to the river.

At Pottstown, eighteen miles below the enormous pollution from Reading, the water supply was found to be drawn from the river, and that, too, at the lower end of the town, below the discharge of much domestic sewage from the town itself. The local physicians have protested against this practice in vain.

The water supply of Phœnixville, drawn from the Schuylkill above the town, was ordinarily very good, but at times in winter, when the river was frozen over, became very bad. The author had discovered the cause of this to be due to the peculiar course of the channel and formation of the river bed just above the pumping station, which caused a deep ice jam that arrested the coarser organic impurities and sent them into the reservoir.

The pollution from Norristown was very serious, especially that from the State Insane Asylum near the town. No attempt to purify any kind of liquid waste before discharging it into Stony Creek had been made, except the water-closet sewage (60,000 gallons per day, from 1,200 people), which had, for two years, been treated as follows: The sewage was first settled in receiving basins, and afterwards filtered—first through blocks made of copperas, plaster of Paris and purifying lime of gas works, and then through finely-pulverized blast furnace slag. By an ingenious arrangement the filters were cleaned by perforated water pipes passing through the bottom, flushing the accumulations back into the settling tanks, from which the sludge was pumped by a steam ejector, and run by gravity to a distant part of the farm. This arrangement worked well, but on account of the nuisance from the unpurified sewage, it had been decided to dispose of the whole by sub-surface irrigation.

President de Kinder read, from a clipping of the *Public Ledger*, of recent date, the following expression used at a meeting lately held by the Homœopathic Society of this city: "In quality, we have a fluid from which a dumb brute may well turn in disgust." Mr. de Kinder said that he was bitterly opposed to the pollution of our drinking water, that he was against the admission of sewage and other deleterious matter into the river,; that the intercepting sewer should be finished without delay, and that the great need for improvement of the distribution system and of large storage basins should be attended to at any cost. He also said that the idea of any sewage matter being allowed to mix with our water supply was very disagreeable, and he would be opposed to it from a point of cleanliness, even if it had no effect upon the wholesomeness of the water.

But, while not wishing to defend, in any sense, either the pollution of the river or any delay in making the needed improvements, he must protest against such extravagant language as had been used by this Medical Society. There was abundant proof to show that impure water was not, of necessity, unwholesome, and eminent authorities were quoted to prove this.

He further stated that chemical analysis of water was not infallible, and that, at any rate, the chemist could only state the results of his analysis. The Sanitary Engineer was the proper authority to draw the conclusions and to sit in judgment upon the question of the

wholesomeness or unwholesomeness of the water supply, for he could judge as to what the effects were in other places where water of a similar quality was in use.

Although heartily in favor of an improved supply, he must yet contend that the death rate of our own city showed that things were not so fearfully black as these gentlemen of the Homœopathic Society would have it. They had a perfect right to think as they pleased, but they should exercise caution before unnecessarily alarming the community. If the water were as vile as they would have it, why had he or his family never been warned by any medical authority against the use of it, notwithstanding several members thereof had been under medical treatment almost continuously within the past three or four years?

Few doubted that running water would purify itself. Exactly what effect the run between Manayuck or the Falls and his own residence had upon the quality of the water, he could not say, but, at any rate, he himself and thousands of others drank it, if not with an absolute relish, at least without feeling any evil effects therefrom.

PROCEEDINGS OF THE ENGINEERS' CLUB OF ST. LOUIS—May 13.—The committee to consider the status of Civil engineers in the employ of the United States, made the following report:

Engineers' Club of St. Louis:

GENTLEMEN—Your committee to consider the status of Civil Engineers in the employ of the United States respectfully reports:

That we find the question of the relation of Civil Engineers to the public works undertaken by the general Government was one of considerable prominence in the debates in Congress, during the late session of that body, and is now in the public press. Also, that there is a general impression that the time has come for an increase in the numbers of the corps of engineers sufficient to enable them to conduct the works under the present organization without employing civilians, or for a reorganization of that branch of the public service, by which it shall be made a distinctively civil service.

Your committee is decidedly of the opinion that the best interests of the military service, as well as those of the civil engineering profession and of the country as interested in both these, demand that the latter alternative be the one pursued.

Your committee regrets to see the discussion of the subject in the public press turning aside from the broad question of creating an organization for the conduct of public works, which shall be equitable and just in distribution of rewards for merit, in promotion to higher rank and pay; which shall recognize the change in the condition of the engineering profession, both military and civil, since the days when both had to be imported from Europe, and which shall allow its engineers to come by judicious selection the same as judges are selected, from the ranks of a profession, and not from the roll of a single school.

To this question, personal matters, past present or future, the value of different schools and mode of training, or the honesty and truthfulness inculcated through certain associations, are alike foreign.

There seems, therefore to be need for a conservative influence, lest the utterances of individuals be taken as expressing the views and wishes of the engineering profession, and lest a discussion of a pure question of public policy degenerate into a controversy about matters of no consequence.

Other clubs than our own have taken up the consideration of the matter, and have appointed committees. It has been suggested that these committees act together, if possible, through correspondence and conference by representations, if practicable, with a view to a joint memorial to express to Congress our view of the matter, and a draft of the legislation required to carry that view into practical effect.

Your committee, therefore, asks to be continued, and for authority to confer with the representatives of other engineer societies, clubs or associations, with a view to concert of action, but without power to pledge this club to anything.—Respectfully,

ROBERT E. MCMATH,
J. B. JOHNSON,
H. S. PRITCHETT,
J. A. OCKERSON,
Committee.

By vote of the club the committee was continued, and the authority asked was granted.

Mr. Frank H. Pond read a paper on "Pumping Machinery and Waterworks." He reviewed the methods of procuring water, from the days of running streams and wells, which developed into the grand aqueducts of Rome to the use of water-pipes for introducing water into dwellings, first employed in London in 1582. Cast iron came into use for making water-pipes in 1810. The oldest waterworks in the country are supposed to be those built at Bethlehem, Pa., in 1754. Now, in 1885, there are 1,040 water works in the country, of which 355 are supplied by gravity, 649 by pumping, and 36 by unknown methods. Then followed an extensive treatise, illustrated by tables, in which the conditions, works and requirements of the modern pump were thoroughly explained. The main points treated of were the pump employing crank motion and heavy fly-wheel, and the duplex pumping engine.

The paper was discussed by Messrs. Moore, Johnson, McMath and Seddon.

ENGINEERING NOTES.

HONINGMANN'S FIRELESS LOCOMOTIVE.—We have already published several notices of Mr. Honigmann's invention, and we may therefore assume that our readers are acquainted with the chief features of the "soda engine." It is generally supposed that Honigmann was the first to make practical use of the "regenerative" properties of a solution of caustic soda, potash, or common salt. This, however, is erroneous. Similar trials were made many years ago in England by Mr. Loftus Perkins, while the essential features of Honigmann's engine were laid before the public by Mr. Spence in 1874. If our readers will refer to Vol. xvii. of

Engineering, they will find on page 124 a paragraph entitled "The Utilization of Waste Steam," where the essential features of Honigmann's engine are described. At the time referred to (January, 1874), Mr. Spence, Jun., proposed to pass the exhaust steam of a high-pressure engine into a solution of caustic soda, which, according to his calculations, would thus be heated to 375 deg. This heated solution was then to be circulated through pipes in an ordinary boiler, where it would serve to raise fresh steam without the use of fuel. As the solution of soda became diluted by the steam condensed in it, it would lose its heat-restoring capacity, and must be regenerated by concentrating it in another boiler of ordinary construction. This paragraph elicited a letter from Mr. Loftus Perkins which we published on page 141 of the same volume (xvii.). Mr. Perkins says there: "I then (in 1864 or 1865) constructed a four horse-power engine, worked by a boiler immersed in a bath of chloride of calcium, the exhaust steam being condensed in the salt and all the waste heat from the engine being entirely absorbed, thus making a perfect heat engine. Succeeding so far the difficulty arose how to get rid of the water absorbed by the salt; this could only be done by distillation, and even if quintuple distillation is used, the coal consumed could not be less than 1¼ lb. per horse-power per hour, whilst a well-constructed, high-pressure, compound condensing engine used less than 1 lb." It is therefore evident, from what has been said, that Mr. Spence, eleven years ago, proposed an engine substantially the same as Honigmann's, and that even prior to that, viz., twenty years ago, Mr. Perkins had actually constructed a similar engine. These engines were, however, supposed to be uneconomical, and thus the matter was dropped, to be taken up again by Mr. Honigmann, who, it is true, has not succeeded yet in using less fuel with his fireless locomotive than with an ordinary engine, but who has shown that the advantages derived from the total absence of smoke and exhaust steam need not be accompanied by any considerable sacrifice in economy of fuel. Thus, though Mr. Honigmann is by no means the first inventor of the soda engine, he is undoubtedly the first who, by his perseverance, has succeeded in introducing it into actual practice.

AERONAUTICAL EXHIBITION AT THE ALEXANDRA PALACE.—The executive of the International Exhibition, which was opened on March 31 at the Alexandra Palace, and which, we trust, many of our readers have made a point of visiting, have been able to secure the support of the Aeronautical Society of Great Britain in holding, in connection with the International Exhibition, an Aeronautical Exhibition. The organization of this exhibition has been entrusted to Mr. Fred. W Breary, the honorary secretary of the society for nearly twenty years, and who has been appointed commissioner for that department. It is to be opened on June 1, and the exhibits that are to be admitted will consist of the following objects: (1) Models of designs for the accomplishment of aerial navigation by mechanical means only. (2) Models of designs for the accomplishment of aerial navigation partly by buoyancy and partly by mechanical means. (3) Models constructed to elucidate either of the two last objects which are capable of flight and carrying their own motive power. (4) Machines constructed upon a scale calculated to carry a weight equal to that of a man, upon the principles advocated by the inventors. (The practicabllity may be demonstrated by the flight of a model of similar character, and of weight-carrying capacity sufficient to enable a judgment to be formed as to the probable efficiency of the large machine when actuated by the power necessary for its support and propulsion, whether by manual or mechanical methods.) (5) Light motors. (It may be observed that light motors are in request for other purposes than aerial navigation. But for the latter object it is essential that extreme lightness shall be a condition. Therefore, only a motor possessing that qualification in proportion to its power with the smallest consumption of fuel in the case of steam or other adjuncts, and capable of working up to one horse-power, at the least, for twenty minutes, will be deemed deserving of the prize.) (6) Balloons, navigable or otherwise. (7) Balloon material and appliances for propulson or otherwise. (8) Kites or other aerial appliances of that character, for saving life at sea, for traction or otherwise. (9) Objects of interest connected with aeronautics.

The amount of the prizes to be given to successful exhibitors is to depend upon the success which attends the appeal to the members and friends of the Aeronautical Society. Further particulars will be furnished to intending exhibitors (who shall have applied for space) at a later date. An interesting feature of the exhibition will be, that advantage is to be taken of the large outdoor space available to invite the competition of amateur and professional aeronauts, so that the disputed question of aerial locomotion by the aid of buoyancy may be conclusively tested. Any form and any appliance is admissible. It is hoped that a contest of balloons for the nearest approach to a given locality may be arranged upon the day or days appointed, to start from the Alexandra grounds. The goal is to be determined shortly before the time of ascent. It is believed that upon such an occasion there would be unusual opportunities for the conveyance of paying passengers. As it is scarcely expected that an aeronaut will claim to drive his balloon against a wind of greater velocity than that by which his balloon can be propelled, but may be able to deflect it considerably from the wind's course, the place of ultimate destination will be determined by the set of the wind at the hour appointed. But if the more ambitious attempt should be desired, then accordingly the goal will be arranged. By preference, a cathedral town will be named. In order to induce aeronauts of any nationality to prepare for these contests, and, as showing that Great Britain is as alive to the advantages of a useful system of aerial locomotion as any other country, it is desired to give such prizes in money as will command competition. In order to make the exhibition a suc-

cess, the Aeronautical Society appeal for assistance in furtherance of a prize fund. Contributions may be forwarded to Mr. Breary, who will act as honorary treasurer, and checks should be crossed "London and County Bank." On this occasion it should be mentioned that the honorary secretary of the society has issued a short pamphlet, in which the relations of the Aeronautical Society with respect to aeronautics are explained.

IRON AND STEEL NOTES.

SLAG CEMENT.—We have on various occasions referred to the ingenious and very successful processes of Mr. Frederick Ransome, for the manufacture of cement from blast furnace slag and lime. The discovery, made about twelve years since by Mr. Charles Wood, that slag run from the blast furnace in a melted condition falls into a fine granulated state, removed one of the main objections to its utilization—the great cost attending its reduction to powder by mechanical means. One of the materials composing the Ransome cement is thus obtained ready for use, and being practically a waste product, its cost is nominal, the expense attending its application being limited to handling. By his earlier method the other material employed—chalk or lime—was ground and mixed with the slag, the combination being then calcined, and again ground; from this resulted a cement possessing very high qualities both as regards quickness in setting, and strength. Very recently, however, Mr. Ransome, following the same line of investigation, has improved greatly on his former simple process, and he has found that the spent lime from gas works may be employed with results as good as those obtained with lime prepared specially for the purpose. In order, however, to get rid of the sulphur with which the lime is saturated when it leaves the gas purifier, Mr. Ransome resorts to a very simple and efficacious device. He mixes a certain proportion of powdered coal or coke with the slag and lime, and when this is exposed to the heat of the calcining furnace, the action of the coal or coke converts the sulphate into a sulphide of lime, that is subsequently entirely got rid of by the introduction of a jet of steam which drives off the whole of the sulphur impurities as sulphuretted hydrogen, leaving the lime quite pure. This, however, is only one of the recent improvements to which we have referred. A highly important modification is the use of a revolving retort for the calcination of the slag and lime. It is found that after the materials have been thoroughly burnt in this manner, they remain in the same fine state of subdivision as when they were placed in the retort, and on being discharged will pass through a sieve of 80 meshes to the inch. The costly process of grinding, which is unavoidable in the ordinary method of manufacture, is thus avoided, while the cement is said to lose none of its useful characteristics in this novel process. Of course this system is equally applicable where fresh lime is employed, instead of the waste material from gas works, only in such case it is unnecessary to add the powdered coke, or to apply the steam jet. We have referred in general terms to the strength of the cement produced by this method; the following Table of comparative tests made with samples of Portland and Ransome cement shows clearly the remarkable qualities possessed by the latter; the samples in each case were 1¼ in. square, giving a sectional area of 2¼ square inches.

Age of sample.	Portland Cement Breaking Load.	Ransome Cement Breaking Load.
	lbs.	lbs.
2 days.	510	740
3 "	698	870
7 "	818	1170
12 "	—	1300
15 "	—	1330
21 "	—	1440
28 "	936	
7 years.	1327	

The foregoing figures speak for themselves, and indicate clearly that the Ransome cement possesses striking advantages over Portland, especially as it reaches a strength within a few days, which is higher than the Portland after seven years. Very important advantages are also found in the simplicity of manufacture, and the suppression of the final process of the cement manufacturer, that of grinding. The plant used is therefore simpler and involves much less expense in maintenance and labor for the production of a given quantity of cement than is required in the ordinary mode of manufacture. When in addition to this, it is remembered that waste materials are employed, it will be easily understood why the slag cement can be made for half the cost of Portland, and the commercial importance of Mr. Ransome's process will be readily appreciated.

RAILWAY NOTES.

UTILIZING OLD STEEL RAILS.—Some interesting experiments have been made recently by Mr. Robert E. Masters, Columbus, Georgia, in melting old steel rails in an ordinary cupola furnace and casting therefrom various useful articles, as brake shoes, truck wheels, &c. Mr. Masters has been experimenting with steel scrap, principally agricultural steel, for some time, having melted some 60,000 lbs. The melting requires a longer time than cast iron, but, when once started, the steel is stated to come down very hot and fluid, although it appears to cool more quickly in the ladle and gum up readily. There is ample time, however, to make large castings. The charge was 1 lb. of coke to 6⅔ lbs. of steel. By itself the steel runs porous, but by adding one-sixth of cast iron, a very solid, close-grained casting is produced, which, Mr. Masters states, is stronger than malleable iron for small castings, and is superior to cast iron for many purpose. An experiment has also been made in melting steel rails at the rate of 5 lbs. of metal to 1 lb. of fuel, at a temperature of 3,000°. Some very fine castings were produced that way. Mr.

Masters appears to have undertaken a most important experiment, and one which promises to be of great value when its success is fully demonstrated, and methods have been fully worked out.

The Railway Administration at Frankfort-on-the-Main have, according to the *Journal of the Society of Arts*, recently repeated some experiments on the lighting of trains by electricity, which are said to have been attended by most satisfactory results. The experimental train was composed of a first, second and third class carriage, and a luggage van, which contained a special compartment for the dynamo and accumulators. The dynamo was of the Moehring type, and was driven from the axle of the wheels of the van, and at a velocity of 700 revolutions per minute, when the train was running at a speed of eighteen to forty-two miles an hour. When the train is running at full speed, the lamps remain in circuit whilst the accumulators are being charged, but when the speed is less than eighteen miles per hour the current is applied direct from the accumulators, a specially constructed automatic commutator regulating its intensity. During the day the lamps are thrown out of circuit, and the twenty-six accumulators are charged by the dynamo when the train is in motion. This installation weighs about 12 cwts., and costs £125. The train was lighted by twelve incandescent lamps, of which two were in the luggage van, two in the third-class carriage, four in the first, and the remaining four in the second-class carriage. The cost of fitting each carriage varies from £3 4s. to £4. These experiments are said to demonstrate the practicability of lighting trains by electricity, the light being perfectly steady during the journey, and at variable speed, and even during stoppages at stations; only at starting a slight oscillation was perceptible. As all is regulated automatically, no attendant is required, it is said, except at starting. The experiments were continued for six weeks, at the end of which time everything was found in perfect order. The cost of lighting is estimated at ten centimes per lamp per hour.

ORDNANCE AND NAVAL.

The Brennan Torpedo.—The naval authorities continue to make experiments with the new locomotive torpedo which has been introduced by Mr. Brennan, a gentleman from Australia. This favored inventor has had placed at his disposal for experimental purposes a casemate on the upper tier of Garrison Point Fort at Sheerness, and a factory has been erected outside the port with a tramway running down to the beach. With these resources at his command Mr. Brennan has so far perfected his idea that a trial of the apparatus has been made which has, it is reported, proved so convincing to the official mind that a sum of £10,000 "on account" has been paid to the fortunate antipodean; this being, it is said, but a tenth part of the reward the inventor will receive for his ingenuity. The torpedo is ejected from the fort by means of a steam engine, at a velocity estimated at 50 miles an hour. There are within the machine two coils of wire wound on spindles each connected with the shafting of a screw propeller. The ends of these wires are made fast to drums on the steam engine within the fort, and as the wires are unwound from the reels in the torpedo on to those on the engine, the screws are set revolving and the weapon propelled forward. The steering is effected by hauling harder on one side or other of the wires so as to make the respective screw revolve faster. Lights screened from the front are placed to show to those on the fort the position of the torpedo. If it be true that the authorities have been led into such surprising liberality as report credits them with, it is to be hoped they are attempting to beguile other nations equally interested in torpedoes with the story of this duplex top-spinning method of propulsion, and are concealing the real mechanism of the Brennan torpedo, the merits of which ought to be very large, if the department values them at £100,000.

The New Brazilian Armor-Clad.—The Aquidabau, which has recently been completed by Messrs. Samuda Brothers, ran a very successful series of trials off the Maplin last week. This vessel is of the same general description as the Riachuelo, full particulars of which were given in a paper read by the late Mr. Samuda before the Institution of Naval Architects last year. The new vessel is 280 ft. long and 52 ft. wide, the displacement being 5,000 tons. The mean draught on trial was 18 ft., the vessel having been designed not to draw much water as she is required for service in the South American rivers. The hull is built of Siemens steel and sheathed with wood. The ram is a solid gun-metal casting and the stern frame is of the same material. The machinery is protected by a water-line belt of steel-faced armor 11 inches maximum thickness and 7 feet wide. There is an armored deck 2 inches thick, carried fore and aft, and arranged to protect the steering gear aft and also to strengthen the ram. The armament consists of four 9-inch 20-ton, breech-loading guns, placed in turrets protected by 10-inch armor. On the upper deck there are two 5¾-inch breech-loading guns at the bow and two similar weapons at the stern. There are fifteen Nordenfelt guns and five ports for the discharge of torpedoes. The engines are by Messrs. Humphreys, Tennant & Co., and are of the three-cylinder, compound type. The Aquidabau was tried in sea-going trim recently. With natural draft the indicated horse-power was 5270 and the speed 15.257 knots. With closed stokeholes and fan draught the power was raised to 6201 indicated horse-power and the speed 15.818 knots. In the forced draught trial only six of the total number of eight boilers were used. Two runs on the mile were made with only one screw working, the speed being at the rate of 11.447 knots, 15° of helm being required to keep the ship straight. A half-circle was turned against the screw in 3½ minutes. A six-hours' coal trial was made. The official report states that the consumption was at the rate of 45 tons a day when the ship was steaming at her contract speed of 14 knots. As the coal bunkers carry 800 tons, the Aquida-

bau could steam over seventeen days on her bunker coal and cover a distance of about 5,700 knots.

BOOK NOTICES.

PUBLICATIONS RECEIVED.

SIXTH Annual Report of the Ohio Society of Surveyors and Civil Engineers. Pamphlet, 156 pp. Columbus, Ohio.

Circulars of Information of the Bureau of Education, No. 1, City Schools of United States. By John D. Philbrick, LL.D. Pamplet, 207 pp. Washington: Government Printing Office.

Planting Trees in School Grounds and the Celebration of Arbor Day. Pamplet, 64 pp. Washington: Government Printing Office.

Proceedings of the Institution of Civil Engineers. Address of the President, Sir Frederick Joseph Bramwell, F.R.S. Physiography by John Evans, D.C.L., LL.D. The Tekapo Bridge, by Frederick William Marshant, A.M.I.C.E. Steam Tramways, by Hon. Richard Clere Parsons, B.A. The Sydney Tramways, by Walter Shellshear, Assoc. M. Inst. C.E.

Thunder Storms of May, 1884; Signal Service Notes, No. 20, by Prof. H. A. Hazen. Pamphlet, 8 pp. and 2 charts. Washington: Signal Office.

FORESTRY IN POLAND, LITHUANIA AND THE UKRAINE. Compiled by JOHN CROUMBIE BROWN, LL.D. London: Simpkin & Marshall.

In preparing this book the writer has simply followed the plan begun some years since of collecting, arranging and publishing the best obtainable information relating to Forestry of different countries. His books, therefore, as they appear in succession relate to regions not described in the previous reports.

The subject is a broad one and comprehends not only the propagation and preservation of the forest trees, but the history of the laws governing such preservation, and also much concerning the physical geography of the region.

The present work contains much that is interesting about a section of Europe not much traveled by the tourist.

HEALTHY FOUNDATIONS FOR HOUSES. By GLENN BROWN, Architect. Science Series, No. 80. New York: D. Van Nostrand.

Even under the present conditions of widely diffused sanitary knowledge few people realize that the health of a household depends rather more upon the earth directly beneath them than upon the surface conditions surrounding them. A bad smell from a neighboring factory may be vexatious and worthy of legal restraint, but still quite harmless when compared with a damp cellar-bottom, which dispenses disease germs that offend directly none of the senses.

The work is divided into four parts: I. Natural Foundations; II. Drainage; III. Foundation Walls; IV. Miscellaneous.

The illustrations are numerous and excellent, and the instructions regarding building or draining are to an eminent degree practical. Designers or occupants of suburban residences should be familiar with the principles here inculcated.

THE FIGURE OF THE EARTH. By FRANK C. ROBERTS, C.E. Science Series, No. 79. New York: D. Van Nostrand.

This little essay, reprinted from *Van Nostrand's Engineering Magazine*, where it appeared as an original contribution, is chiefly of interest to students of physical and mathematical science.

The object of the author has been to arrange in compact form the important mathematical principles for the deduction of the Figure of the Earth upon the spheroidal hypothesis. This is an important service rendered to the student, as most of the literature upon this subject is burdened with voluminous mathematical discussions of collateral subjects.

The subject is presented in two distinct parts: I., Historical. II., The Oblate Spheroidal Hypothesis.

The first part or section may be read with profit by any student of Physical Geography. The second section supposes a moderate amount of mathematical knowledge in the reader, but still much less than is generally called for by previous writers.

A TEXT-BOOK ON THE MECHANICS OF MATERIALS, AND OF BEAMS, COLUMNS AND SHAFTS. By MANSFIELD MERRIMAN. New York: John Wiley & Sons.

This work differs from other good works of its class in presenting just what is comprehended in the above title and in omitting the tables of results, which, although valuable to the working engineer, are an encumbrance in a text-book and present a forbidding look to the learner.

This book presents the following topics in order, in chapters:

I. The Resistance and Elasticity of Material.
II. Pipes, Cylinders and Riveted Joints.
III. Cantilevers and Simple Beams.
IV. Restrained Beams and Continuous Beams.
V. The Compression of Columns.
VI. Torsion and Shafts for Transmitting Power.
VII. Combined Stresses.
VIII. Appendix and Tables.

To fully fit the treatise for instruction purposes, Prof. Merriman has added problems to each section.

The illustrations are exceedingly well designed to illustrate each separate topic.

The well-earned reputation of the author, both as writer and instructor, renders any comment on the quality of the work superfluous. The investigations presented here belong to a field of labor in which the author is entirely at home, and in which he may be regarded as an authority.

GAS ENGINES. By WILLIAM MACGREGOR. New York: D. Van Nostrand.

The use of the gas engine is rapidly extending. With the introduction of electric lighting it received a new impetus.

Wherever in our large cities a motor is required for a temporary service at more or less irregular intervals, and where convenience is valued more than economic efficiency, there the gas engine finds favor. The question regarding the principles of action of this or that popular

gas motor are much more frequently asked than answered.

The book before us is designed to answer queries that are daily asked about engines which are constantly being set up in connection with dynamic electrical circuits.

The treatise deals first with the historical phase of the subject and describes some of the forms from which it may be concluded the present forms have been directly evolved.

Part I. deals with engines working without compression, and includes descriptions of the Lenoir, Hugon, Bischopp, Andrews and Sombart engines, illustrated with an abundance of diagrams.

Part II. explains the construction and action of gas engines working with compression, and is divided into two chapters; one devoted to that class of engine in which the whole of the four periods of the cycle are performed in the motor cylinder; and the other to that class in which part of the cycle is performed in a pump or separate cylinder. The Clerk engine being the representative of the best latter class.

Part III. presents in six chapters the theories of the different kinds, and will be to the student of thermo-dynamics the most valuable portion of the book. The book is sure of an extensive demand, because it answers in so direct a manner the questions that are daily asked among mechanical engineers.

HOW TO DRAIN A HOUSE: PRACTICAL INFORMATION FOR HOUSEHOLDERS. By GEO. E. WARING, Jr., M. Inst. C. E., Consulting Engineer for Sanitary Drainage. New York: Henry Holt & Co, $1.25.

The author, a well-known authority and writer on sanitation, deals with the best methods and appliances for the plumbing and draining of houses, and writes on this subject of ever-growing importance to the householder in his usual vigorous and elegant style. The larger part of the contents have recently appeared in articles contributed to the *Century Magazine*. To these, which had special reference to the details of pipes, traps and fixtures inside of the house, the author has added important chapters on the sewage disposal for isolated houses, particularly by the method known as "subsurface irrigation." It is to be regretted that the illustration of the book should not have been rendered in a more uniform and better style. The remarks made in Chapter XXIV., on the relations existing between owners, architects, sanitary engineers, and plumbers deserve earnest and thoughtful attention.

While the book is principally intended for householders, it contains much that is of interest and value to the rapidly increasing number of engineers, who make healthful house construction a special study.

AN ELEMENTARY TREATISE ON HYDROMECHANICS. With numerous examples. By E. A. BOWSER, Prof. of Mathematics and Engineering, Rutgers College, New Brunswick, N. J. D. Van Nostrand, Publisher.

This work on the equilibrium and motions of fluids possesses in a marked degree the essential features of a good text-book. The definitions and axioms of the subject are clearly stated and their relative importance made apparent to the eye in the text. Theorems based upon them are demonstrated as concisely as is consistent with completeness of treatment, and the principles are immediately applied to questions of a practical kind and fully illustrated by numerous examples. The elements of this science are presented in a way to encourage habits of thought and reflection, and at the same time, to fit for practical application, by giving knowledge of an extremely useful kind.

The book is suggestive, containing many references to the original papers on the many branches of this subject and indicating the line of study to those who wish to investigate further.

The first division is hydrostatics. The opening chapter deals with the equilibrium and pressure of liquids and applies the principles to the stability of embankments.

The second chapter is devoted to floating bodies and specific gravity, describing the instruments used in determining it and illustrating by many very interesting and useful examples.

The next chapter takes up the topic of gases; and in it Boyle and Mariotte's law is very clearly presented, and used in explaining the relations between the pressure, temperature and density of a mass of gas. Special consideration is given to the atmosphere, so far as it falls in line with the subject; and the theories of the barometer and thermometer, together with their applications are fully treated.

The second division is given to hydrostatics. It is practical in character, treating of the motions of fluids in pipes and taking into account the various elements, that determine the velocity of flow and amount of discharge.

A point of special interest is the attention given to the coefficients of resistance, due to friction, enlargement of section of pipes and so on. Many practical formulæ are theoretically derived and their application in practice fully set forth. The book concludes with a description of various machines whose action depends on the properties of air and water. The author has not been content to give the bare elements of the subject, but has furnished much valuable information and suggestion in such a way as to stimulate interest and study and so to contribute to the value of this book for training and instruction.

MISCELLANEOUS.

IN the preparation of alumina, according to the *Chemiker Zeitung*, ferro-silicium is mixed with fluoride of aluminum in equal proportions, and the mixture is exposed to a fusing heat. The materials decompose each other, and volatile fluosilicium with iron and aluminum, are produced, the latter two bodies being alloyed together. In order to extract the valuable aluminum, a copper alloy is formed by melting the iron alloy with metallic copper; by reason of the greater affinity of the copper for aluminum this is secured, leaving with the iron only a slight residue of aluminum. When the fused mass is cold, copper-bronze and iron have so settled that both bodies can be easily separated.